THE EFFECT OF ALCOHOL ON PSYCHO-MOTOR REACTIONS, STUDIED PARTICULARLY FROM THE MEDICO-LEGAL ASPECT.

Volume 1.

by

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NOTE

In view of the considerable bulk of statistical material, which had of necessity to be included in this thesis, I have taken the liberty of binding the text, and the tables and graphs, separately, in order to facilitate the work of the examiners.

C O N T E N T S

VOLUME 1.

INTRODUCTION.

"Consumption of intoxicating liquor and efforts to control anti-social results are well-nigh universal phenomena. From the laws of the ancient Hebrews and the discourses of the Greek philosophers to the Anglo-Saxon dooms, and down to the present time, control of the harmful social effects of drunkenness has been a matter of public concern." (1).

The importance of alcoholic intoxication to all members of the community has been greatly enhanced by the invention of the internal combustion engine, the mass production of relatively inexpensive motor cars, and the consequent increase in the numbers of vehicles on the roads. Until the advent of the motor car age the intoxicated individual was more of a danger to himself than to others and consequently no drastic measures were called for to safeguard members of the public. According to the Licensing Act, 1872 S.12. the penalty for being drunk while in charge on any highway or other public place, of any carriage, horse, cattle or steam engine, is a fine not exceeding 40/- or imprisonment with or without hard labour for not exceeding one month. (2).

A mechanically propelled vehicle capable of relatively high speeds can, in irresponsible hands, become a lethal weapon of great potentialities, and the law has very wisely made provision for the severe punishment of anyone who

(1) Ref. Hall 20. (2) Ref. Dingle 43.

jeopardises public safety by being in charge of such a vehicle while suffering from alcoholic intoxication. Such offenders are now liable to a fine not exceeding £50 or to imprisonment for a period not exceeding four months, or to both (3) under the Criminal Justices Act, 1925. S. 40 (4) and the Road Traffic Act, 1930.

When being "drunk in charge of a car" became a relatively serious offence it became customary to have expert medical evidence on one or both sides. The principal purpose of a medical examination in such cases is to eliminate illness as a cause of the accused's apparent drunkenness, and there is no doubt that this is valuable. After some experience of this type of work I realised that the verdict given by the medical practitioner concerned is entirely a matter of opinion, based on his own observations of a series of clinical tests, and perhaps unconsciously coloured by his views on alcohol in general. It is highly unsatisfactory when two doctors examine the same individual, at the same time, and form divergent opinions as to his fitness to drive. This leads a bench of magistrates to lose faith in expert evidence, and it seemed to me that it would be a great advantage if some completely accurate mechanical measurement of drunkenness could be elaborated which would be an adjunct to the clinical examination.

(3) Ref. Dingle 43.

(4) Ref. Report of Committee on Tests for Drunkenness. 36.

It was with this object in view that the experiments described below were undertaken.

The problem of deciding which faculty would lend itself to accurate measurements next arose, and ultimately the reaction time was selected as an obvious choice. The reaction times to light and sound are vitally important to drivers of motor cars. The avoidance of an accident may depend solely on the driver's swift reaction to the situation, and, as it is known that alcohol increases the reaction time, it seemed reasonable to try to demonstrate the degree of intoxication by determining the alteration in this figure.

(2) REVIEW OF THE TESTS FOR DRUNKENNESS AT PRESENT IN USE.

Up to 1927 there was no uniformity throughout the country in tests for drunkenness, each individual examiner utilising those for which he had a personal preference. In order to try to clarify the position and to establish uniformity the Council of the British Medical Association, on 21st. October, 1925, appointed a committee with the following terms of reference:-

> "To consider and report on the present tests for 'drunkenness' with recommendations as to their modification or improvement".

The Committee reviewed the tests in use at home and abroad at that time and in their report (1) recommended a selection of tests to be employed in this type of work.

One very important contribution made by the Committee was the formulation of a definition of the word "drunk". There is no statutory definition of this state, and it was desirable that the public, and particularly magistrates and solicitors, should have some authoritative definition which would meet modern requirements.

The interpretation of the expression "drunk" by the bench trying a case, if that word is introduced in the evidence, may affect their decision very materially. It is expected by some that only if the accused is

(1) Ref. Report of Committee on Tests for Drunkenness. 36.

helplessly intoxicated will a conviction be recorded. This view may have been satisfactory towards the end of last century but it must be realised that relatively small amounts of alcohol may seriously affect the efficiency of the driver of a motor car and therefore, he need not be grossly under the influence of alcohol to become a danger to his fellow road-users.

The Committee lays stress on the fact that "there is no single test which taken by itself would justify a medical practitioner in deciding that the amount of alcohol consumed had caused a person to lose control of his faculties to such an extent as to render him unable to execute safely the occupation on which he was engaged at the material time". They furthermore emphasize that "there is no single symptom due to the consumption of alcoholic liquor which may not also be a sign of some other pathological condition".

The Committee recommended a number of tests for general use. These tests are numerous and this very fact indicates the present unsatisfactory state of affairs. In addition they are subject in actual practice, to individual interpretation, and a person's unfitness to drive is not at the moment capable of any sort of scientific proof. Defending solicitors are able to make considerable capital of this fact, and often a skilfully executed defence may extricate the accused when, in fact, it appeared he should have been convicted.

From the point of view of the medical witness these cases are most unsatisfactory as he has nothing beyond a more or less vague expression of opinion that he can offer to guide the court.

Some workers (2) are so dissatisfied with the recommended tests that they advocate dropping them altogether. After over 25 years experience as a Divisional Surgeon of the Metropolitan Police, Fairlie holds that in many instances, the tests are either unfair to the person tested or prove nothing. He maintains that "many persons say and do things perfectly well in the ordinary course of life, but, when suddenly called upon to do them, especially if they know they are being observed, their performance may be very faulty. On the other hand, many drunken persons are able to perform extraordinary acts successfully, particularly if they are accustomed to similar actions in every day life. The fact that they are able to carry out these particular acts creditably is no proof of sobriety".

Fairlie recommends that merely an ordinary routine medical examination should be conducted. If the examination is exhaustive, and includes a careful clinical examination of the central nervous system, this will meet the case, because in the course of it the accused's powers of

(2) Ref. Fairlie 15.

co-ordination will be estimated and most of the tests to which Fairlie objects are pointed specifically in that direction. One objection to this suggestion is that the result depends entirely on the thoroughness of the examination, and a perfunctory examination of the pupils, heart, and lungs, is of no value. Unless some definite routine is laid down in which students can be instructed, no uniformity will be achieved, and a practitioner unaccustomed to this type of work will find himself at a loss when confronted with a case.

In my opinion, one of the most valuable tests is an enquiry into the memory of the subject for incidents within the few hours previous to the examination, and his estimation of the passage of time. All normal persons should be able to give an account of the happenings of the preceding three or four hours in a sensible and satisfactory manner, and this most alcoholics fail to do.

I use one test which is not recommended by the British Medical Association Committee. This consists in asking the subject to copy simple diagrams on squared paper. This test can be satisfactorily passed by a child of eight or ten years and I find it valuable for two reasons. In the first place it requires no particular skill oreducational attainments, and can be applied to the relatively illiterate, and, in the second place, it provides me with one piece of concrete evidence which can be placed before the court and on which it can draw its own conclusions.

During the last quarter of a century an enormous amount of experimental work has been done on the question of the metabolism of alcohol, particularly in Sweden, Denmark, Germany and America.

Miles (3) gave a number of men of different body weights the same dose of alcohol. The one with the highest urinary alcohol showed the greatest clinical manifestations and he concluded that there is a relationship between the alcohol effect, urinary concentration, and body weight. The man with the lowest body weight showed the greatest alcohol effect and the highest urinary concentration. This however did not apply in the whole series of cases so that probably there is some other factor such as the differences in individual absorptive powers. Body weight and tolerance, both inherent and acquired, are undoubtedly factors of importance.

Miles found that the toxic symptoms and the urinary concentration do not run absolutely parallel. There is a proportionate rise in both, but towards the end of the period, and in fact during most of the down-gradient, the decrease in toxic symptoms exceeds the fall in the urinary alcohol, i.e., there is sudden diminution of intoxication. This corresponds to Mellanby's findings (4). He draws the conclusion that descent of the alcohol curve not only means improvement but "the improvement may be so pronounced

(3) Ref. Miles 33. (4) Ref. Mellanby 31.

that a man may apparently be more sober than on occasions when less alcohol is present in the blood". The explanation of this probably lies in the fact that the intensity of the stimulus given to the central nervous system governs the degree of the response. Once the nervous system has become stabilised the disturbing element is not nearly so potent in its effect. Mellanby also confirms the influence of body weight on the blood alcohol concentration. He found that if a dog varies in weight then, if it receives the same volume of alcohol on different occasions, the amount in unit volume of blood is inversely proportional to its body weight.

Blood alcohol tests have been used as a routine for several years in cases of traffic accidents in different countries. This has resulted in a mass of data being available relating the results of such tests with the clinical diagnosis regarding the presence or absence of intoxication in persons involved in road accidents. The published findings for different countries are on the whole in striking agreement. A very useful summary of recent work is embodied in the Report of the Medical Research Council 1938 (5). According to this publication "an analysis of 3,000 cases by Hansen of Oslo (1938) showed that 1,126 of these had a blood alcohol concentration between 0.15 and 0.2%. This is in accordance with the opinion expressed in Germany by Strohmayer (1937) that the blood alcohol concentration most conducive to accidents is about 0.18%. Clinical examination of

(5) Ref. Report of M.R.C. 3.

Hansen's cases showed that 41% of the subjects with a blood alcohol concentration of 0.10% and 91% of those with a concentration of 0.2%, were affected by alcohol. These proportions agree closely with similar figures published previously by Widmark (1932) and Jungmichel (1935). Psychological tests on the competence of motor drivers after taking alcohol indicate however that driving may be affected by concentrations of alcohol smaller than those needed to affect the behaviour in ordinary clinical tests. Sachsenberg (6) reported that about half the subjects of his experiments were incapacitated for safe driving by a blood alcohol concentration of 0.05%, and that none of those tested was capable of driving safely with a blood alcohol concentration exceeding 0.14%. Strohmayer (1937) made a careful analysis of 106 accidents and concluded that in concentrations in the blood of less than 0.11% alcohol could rarely be blamed for the accident, and that this was true of some cases where the alcohol content was as high as 0.14%. He suggested that 0.18% was a particularly dangerous concentration since the driver might not be obviously drunk but was very likely to do the wrong thing in the event of an emergency; for example he noted that the accident histories showed that drivers in this condition nearly always swerved instead of applying the brakes. He concluded that clinical examination was not really reliable because it estimated the outward appearance of a person and did not determine his capacity to manage a

(6) Ref. Sachsenberg 39.

motor in traffic emergencies. Huber (1938), as a result of the analysis of 500 cases, came to a similar conclusion. These writers therefore claim that the ordinary clinical tests for alcoholism are unsatisfactory in that they do not detect derangements of function that are sufficient to be a contributory or even the major cause of traffic accidents. According to this view 10% of persons with 0.2% of alcohol in the blood who were found unaffected by alcohol on clinical examination, although not affected sufficiently to change their ordinary behaviour were nevertheless likely to be dangerous in traffic emergencies. Sachsenberg's results indicate that anyone with a blood alcohol concentration of 0.14% or more is affected by alcohol and in the United States a similar definite limit (1.5 per mille) has been accepted by a committee of the National Safety Council. This simple rule expresses a strong probability but it can be criticised on scientific grounds in that it takes little account of individual variation in response which has been found in all cases when the actions of drugs have been accurately studied on large populations. Alcohol does not constitute an exception to the general rule. This variation can easily be demonstrated in populations of mice, and Newman and Card (1937) showed that different dogs may exhibit a widely varying degree of drunkenness at the same blood alcohol level. They also showed that habituation to alcohol raised the alcohol level at which drunkenness appeared. A comparison of the results of the blood alcohol tests and clinical examination suggests an individual variation in the case of alcohol at least as great as that found with most drugs whose action on large populations has been studied. There is general agreement that there is a variation in the effect of small doses of alcohol and that some persons with a blood-alcohol concentration below 0.1% may be dangerously under the influence of alcohol. If this be admitted then it follows either that alcohol is an exception to all the known laws of variation, or else that variation occurs in the other direction also. This criticism implies that the rule holding good for the average individual may be subject to occasional exceptions. As regards the average individual however all the available evidence supports the view that blood-alcohol estimations correctly indicate the extent to which he is under the influence of alcohol.

Any form of alcoholic liquor can cause drunkenness if such a quantity of it is taken at once or within a short time as will lead to the presence of the drug in the blood above a certain proportion, which, in the case of the average healthy adult may be put provisionally at from 0.15 to 0.20%."

Newman and Fletcher (7) while admitting that there is a high correlation between alcohol concentration and

(7) Ref. Newman and Fletcher 35.

intoxication in any large series of cases, emphasize the unfairness of setting a theoretical blood alcohol level above which unfitness to drive can be presumed, because of the factor of individual variation. In those states in America where the level of 150 m.g. per 100 cc. of blood is accepted as the critical level on the recommendation of the National Safety Council, this fact is lost sight of. In order that a man may be convicted of drunken driving because his blood alcohol concentration is over 150 m.g. per 100 cc. it is essential that this blood alcohol concentration be shown to produce legal intoxication not in a majority of individuals but in every individual. Failing this it is inevitable that certain convictions will be unfairly obtained.

Bogen (6) found a high degree of correlation between the breath and urinary alcohol concentrations and the degree of clinical intoxication. According to his figures with alcohol concentrations below 100 m.g. per 100 cc. none was adjudged intoxicated, with 100 to 200 m.g., 50% were intoxicated, with 200 to 300 m.g., 75% were intoxicated and with 400 m.g. and over, almost all were intoxicated. From this he concludes that tissue alcohol concentration is the best criterion of drunkenness. Yet the variation in tolerance to alcohol is apparent from his own figures, which show that at alcohol concentrations of from 100 to

(6) Ref. Bogen 6.

200 mg. per 100 cc. half the individuals were intoxicated while some few were not so diagnosed with over twice this concentration, and if we were to subscribe to the limit of 150 mg. per 100 cc. laid down by law in certain American states at least 25% of the accused persons would have been wrongly convicted of drunkenness on the basis of tissue alcohol concentration.

Jetter (9) obtained similar results in a large series of cases. Considering only his extreme readings he found 10% intoxicated at a blood alcohol level of 50 mg. per 100 cc. and 93.3% at 400 mg. per 100 cc. Thus an occasional individual was not considered intoxicated at a blood alcohol concentration eight times as high as that at which 10% were judged intoxicated.

Smith and Stewart (10) are more conservative considering the test of value in determining how much alcohol has been ingested but not in the diagnosis of the degree of intoxication.

Chemical tests for drunkenness may be based on the blood alcohol concentration, the urinary alcohol, or on the alcohol in the expired air. In the opinion of Smith and Glaister (11) "it seems likely, on the whole, that urine contains alcohol in concentration about equal to that of the blood at the moment the urine is secreted. During the post-absorptive period, the blood alcohol concentration is steadily falling. Hence of the urine

(9) Ref. Jetter 24. (10) Ref. Smith and Stewart 41.
(11) Ref. Smith and Glaister 42.

which has accumulated in the bladder and is passed at a certain time, most has been secreted at a time when the blood alcohol was higher than at the time the urine is passed. The urine alcohol, in fact, represents the average concentration in the blood during the whole time the urine has been accumulating. Consequently, if samples of blood and urine are obtained simultaneously, the latter usually contains the higher concentration of alcohol. This is particularly true of urine secreted entirely during the post-absorptive period. Since the time during which the blood alcohol rises is relatively short, it still holds, though in lesser degree perhaps, for urine secreted over the whole period of two or three hours subsequent to ingestion. A figure fairly generally accepted for the (average) ratio of urine alcohol to blood alcohol is 1.35 to 1.00, but we believe this figure to be subject to considerable variation according, inter alia, to the time of collection of the urine. In the expired air, the concentration of alcohol appears to be approximately a tenth of the concentration in the blood, but though this is capable of affording a rough guide to the amount of alcohol in the body, it does not permit calculation with the accuracy obtainable from blood analysis".

When an estimation of the blood-alcohol concentration is carried out the blood tested is venous blood. It may well be that the concentration of the alcohol in the urine, at the time it is secreted, approximates more closely to the alcoholic concentration in the arterial blood.

From this review it is quite obvious that while statistically there is a close correlation between the concentration of alcohol in the tissues and the clinical condition, the fact of individual susceptibility is so serious that it is highly improper to establish a fixed level of blood or urinary alcohol above which an individual is to be judged unfit to drive. The figures quoted above indicate clearly that this would lead to serious miscarriages of justice in both directions. It is a mistake to carry over the apparent tendency of individuals with the highest blood-alcohol concentrations to exhibit the greatest loss of skill, into the arbitrary setting up of a fixed blood-alcohol concentration, at which a majority of persons are intoxicated, to apply to all individuals equally. If any blood-alcohol concentration is to be accepted as absolute proof of intoxication in the legal sense, it is essential that it be one at which experience has shown that no man, regardless of his inherent or acquired tolerance, would be adjudged clinically fit to drive a car. Such a figure would have to be so high that many grossly intoxicated individuals would escape detection if the chemical tests alone were used.

The present position seems to be that chemical tests for tissue alcohol are of value only as an indication of alcohol intake with the possibility of estimating the amount consumed.

The only conclusion which can be reached is that the present position is highly unsatisfactory from the point of view of all concerned. However, in the absence of any improved technique, the best possible use has to be made of the accepted methods at present available.

It cannot be too strongly emphasised that the examiner's opinion must be based on the results of all his observations both clinical and chemical, and that isolated tests are of no value. Chemical tests can no more be considered alone than any of the clinical tests recommended by the British Medical Association Committee on Tests for Drunkenness, and the results of any analysis made must be assessed in conjunction with the clinical condition. In view of the fact that an opinion must be based on the consideration of a mass of data any additional fact which can be added to the sum total of evidence is of importance.

Even though it may be possible, at some future date, to establish a scientific test for fitness to drive which is acceptable to the courts, illness or injury as the complete, or partial, explanation of the accused's condition will always have to be eliminated by clinical examination.

(3) REVIEW OF THE LITERATURE.

1. Some Clinical and Pharmacological Effects of Alcohol.

(a) Pharmacological Action.

Because of certain outward manifestations of its ingestion alcohol used to be regarded as a stimulant, and this fallacy is still perpetuated in some institutions where the ward brandy bottle is labelled "stimulant". For many years now it has been recognised that its action is purely and simply narcotic; its apparent stimulant effect being due to its early action on the higher cortical centres resulting in the suppression of certain inhibitions. It is this mild narcosis which produces the traditional good fellowship of the public house. By virtue of this depression of the more critical faculties, due to the loss of the controlling influence of the more lately developed cortical centres, the lower centres are capable of less restrained independent action.

The effect of alcohol on the excitability of the central nervous system has been studied by various workers experimentally.

G. & P. Varé, Verdier and Vidacovitch (1) having observed that in man the taking of alcohol may be followed by psychic excitation, or by confusional symptoms with slowing of ideation, depending on the dose taken, and the phase of action of the poison, wondered whether the diversity of symptomatology did not correspond to variations

(1) Ref. Varé G. & P., Verdier & Vidacovitch. 46.

in the degree of excitability of the psycho-motor centres. They postulated that the external manifestations of excitement corresponded to a lowering of the threshold of these centres, and the mental slowing to an increase in the threshold of excitability. Using trephined dogs they administered alcohol by stomach tube and then stimulated the motor centres of the brain electrically measuring the resistance to the stimulus. Using relatively small doses of alcohol solutions they found that during the phase of psychic excitement the threshold of the motor cortex is low, but, as the intoxication deepens, and forgetfulness and stupor take the place of excitement, the threshold of the motor area is appreciably raised.

Several workers have investigated the effect of alcohol on the reflexes of the frog. Meihuizen (2) observed the effect of various drugs on the reflex excitability of the frog to induction shocks. He found that 1 cc. of 10% alcohol decreased reflex excitability, that the effect appeared within 15 minutes, and reached its maximum in from 45 to 90 minutes.

Winterstein, according to Dodge and Benedict (3), found that using doses of alcohol up to 5% of the circulation of the frog, he could produce complete inexcitability of the cord.

In an exhaustive study of the effect of alcohol on the reflexes of the frog, Hyde, Spray and Howat (4) found

(2) Ref. Meihuizen 30. (3) Ref. Dodge & Benedict 12.
(4) Ref. Hyde, Spray & Howat 23.

that doses stronger than 1 cc. of 15% alcohol per 10 grams of weight depressed all the reflexes. The depression, they found differed for different reflexes and for different doses, came on in 10 minutes, and lasted one to one and a half hours.

That these effects on reflex action are due to the influence of the drug on the nerve centres activating the muscles, and not on the muscles themselves, has been proved (5). Muscles separated from the nervous system and perfused with blood and alcohol in doses equivalent to 70 cc. in man, or nearly 5 ounces of whisky at proof strength, showed no effect on their contractible power or other functional properties.

It is generally accepted that alcohol acts on the synapses in the central nervous system delaying the passage of the exciting impulse (6). The higher synapses are more resistant than the lower to the passage of the nervous impulse and, on the assumption that all synapses are equally affected by alcohol, it follows that the alcohol will raise the resistance of the higher synapses to the point of impermeability sooner than the lower, less resistant, synapses. The motor centres in the brain are not the most highly evolved, and it seems possible that the increased exitability, or reduced threshold of those centres noted by Varé, Verdier and Vidocovitch, was

(5) Ref. Report of M.R.C. 2. (6) Ref. Report of M.R.C. 3.

due to the loss of the inhibiting action of higher centres on these, the depressant action of the drug on the motor centres being masked by their release from higher control. The work of Travis and Dorsey (7) supports this hypothesis suggesting as it does that a reduction of higher centre inhibition is accompanied by freer, and subsequently faster, activity on the part of the subjacent centres.

The present complex nervous organisation of man is due to the super-position of more adequate biological structures on less efficient ones. The latter are permitted to retain a measure of autonomy, but physiologically the tendency seems to be to make them dependent for their ultimate expression on their release by the more recently acquired structures.

Alcohol, in common with many other narcotics and anaesthetics, appears to act first on the more recently acquired structures, and successively influences centres of a lower order.

It can, therefore, I think be accepted that the action of alcohol on the central nervous system is purely depressant in character.

In the popular mind alcoholic intoxication is associated with "boisterous, disordered and even violent activity of mind and body". It has previously been recorded (8) that this aspect of drunkenness appears

(7) Ref. Travis and Dorsey
(8) Ref. Report of M. R. C. 3.

usually under conditions calculated to stimulate the emotions and is not observed under experimental conditions. This fact I have observed personally and it further supports the view that alcohol is a narcotic and not a stimulant. The subjects exhibited none of the symptoms mentioned above. Their first subjective sensation was one of lassitude and progressive disinclination to mental or bodily activity. This was followed by inability to concentrate and, though I provided ample reading material to alleviate the boredom of waiting between observations, very few of the subjects made much use of this facility. Later the more seriously affected subjects became sleepy, and many were actually overcome by sleep.

(b) The Influence of Alcohol on Neuro-muscular Mechanisms and Reflexes.

The most important work in this field has been done by Miles (1) who published his results in a monumental treatise. When dealing with an actual case of drunkenness it is customary to observe an increased pulse rate, and usually the pulse is of the full, bounding type. As these persons are, at the time of examination, under considerable emotional stress because of their unusual surroundings, it is difficult, and I think unfair, always to attribute the pulse rate as such to the action of alcohol. Miles has proved that alcohol does produce an elevation of pulse rate and that the effect can be

(1) Miles 33.

observed up to 2 to $3\frac{1}{2}$ hours after ingestion. The fact that the heart rate is quickened after alcohol, whereas the demands are supposedly the same as in the control experiments, is interpreted as a decrease in physiological efficiency, due to a disturbance in the neuro-muscular co-ordination of the cardiac mechanism.

Miles found an increased latency and decreased response in the protective lid reflex, and a consistent decrease in speed of about 8% in the movements of the eye from one object to another. The eye movements were judged by Dodge and Benedict (2) to give the most characteristically trustworthy results for the effect of alcohol. They chose the protective lid reflex as this reaction is free from arbitrary control, and can neither be simulated nor voluntarily inhibited. Their conclusions are as follows:- "Thirty cubic centimetres of alcohol increased the latent time of the response to the first stimulus in four out of five subjects by an average of 5.9%. At the same time the extent of movement was decreased in five out of six subjects by an average of 10.7%. Similarly 45 cc. of alcohol increased the latent time of the first reflex 9.5% and decreased the extent of the movement 28.5%. In this case there was but one exception out of six subjects. Since an increased latency and a decreased amplitude of reflex movement are the usual physiological indications of decreased

(2) Ref. Dodge & Benedict 12.

reflex excitability, we must conclude that, in the case of the protective lid reflex, moderate doses of alcohol tend to depress the excitability of the reflex arc. In the case of the lid reflex where the data include the effects of both 30 cc. and 45 cc. doses, the average depression varies directly with the dose".

The total results of all the data indicate that in the case of the lid reflex moderate doses of alcohol tend to depress the excitability of the reflex arc.

Their study of the eye reaction to a suddenly appearing peripheral stimulus showed that 30 cc. of alcohol decreased the reaction time by 5.4% on the average. When 45 cc. were given the reaction time increased in all six subjects by 15.6%

Using doses of from 21 to 28 grams, and from 32 to 42 grams of alcohol diluted, Miles also made observations on the eye movements. He found that after the smaller dose there was a consistent decrease in speed amounting to about 7% while the larger dose produced an average decrease in speed during the two hours following ingestion of approximately 9%. In the opinion of Miles the estimation of eye movement stands intermediate between a simple speed of performance test on the one hand, and an accuracy measurement on the other. In earlier publications of results of finger-movement and eye-movement tests it is characteristic that the eye-movement shows the larger effect. It is quite obvious that the eye movement contains a requirement for accuracy of adjustment which does not exist in the finger movement. Although in Miles' data no attention is paid to the amount of corrective movement which is required to bring the eye absolutely to the fixation point, still the factor of accuracy is playing a prominent role. When the eye is moved suddenly from one point to another in this test the second point is seen by indirect vision, the distance estimated, and the co-ordination elaborated accordingly. The eye movement test thus combines speed and accuracy, and, as a neuro-muscular process of fundamental importance to the efficiency of the individual, is rather strongly depressed by such amounts of alcohol as were used in these experiments.

The work of Dodge and Benedict and of Miles therefore demonstrated that alcohol produces a marked depression in eye reflexes and movements.

Many experimenters have investigated the effect of alcohol on the patellar tendon reflex, measuring the height of the response and the latency of the reaction.

Tuttle (3) measured the height of excursion of the knee jerk by means of a lever actuated by a wire attached to the subject's heel. The lever recorded on a drum. Varying quantities of alcohol or synthetic gin were given to the subjects after they had been kicking normally for

(3) Ref. Tuttle 45.

about half an hour. The author concludes that "the effect of alcohol on the knee-jerk may be either excitatory or depressant. Of 12 cases 9 showed augmentation, 2 depression, and 1 no effect. The fact that the data show a marked variation in the threshold for alcohol indicates that the dose was too small in the case of the subject who showed no effect. Both subjects whose knee-jerk was depressed were accustomed to drinking alcohol daily. Those whose knee-jerk was augmented drank alcohol only occasionally".

Dodge and Benedict (4) report that moderate quantities of alcohol lessened the speed and amplitude of the movements of the knee reflex in healthy subjects. Miles (5) found that the speed of the knee-jerk was first lessened and later increased while the amplitude was irregularly affected throughout.

Miles (6) also studied the effect of alcohol on the speed, amplitude, and variation in amplitude, of finger movements. He showed that 27.5 grams of alcohol diluted to 1000 cc. decreased the speed by 12%, the amplitude by 15%, and increased the variability roughly 50% in the 2 hours following the ingestion of alcohol. The three aspects of finger movement investigated are however not independent of one another. Possibly any reduction in the average amplitude of such movement produces a larger percentage variability and the effort to keep up the speed may operate

(4) Dodge & Benedict 12. (5) Ref. Miles 32.

(6) Ref. Miles 33.

in the same direction. The results, taken at face value, indicate that the alcohol produces a definite but rather slight decrement in speed, while the smoothness and easy facility of the performance are strikingly interfered with. The experimental results of the action of alcohol on this simple motor co-ordination test are in keeping with those found in typewriting experiments which will be considered later. The alcohol in both cases affects the smoothness and quality of the work.

Eye-hand co-ordination was tested (7) with a pursuit pendulum. This test measures the co-ordination of eye and hand by the simple method of observing how much liquid a subject can catch from a swinging pendulum. Miles found that dilute alcohol (27.5 grams in 1000 cc. of water) measurably and uniformly, affected his efficiency. The amount of liquid he was able to catch was reduced on the average about 5% during the two hours following ingestion, and the smoothness and regularity of co-ordination between successive trials was reduced somewhat more than 30% on an average. The alcohol effect in the experiment was therefore quite definite, and, if the task were a factory process, it would probably be considered large enough to have practical importance in reference to the working efficiency of the subject.

When continuous co-ordination was necessary, as in the case of experiments with the pursuit meter, the same

(7) Ref. Miles 33.

dose of alcohol decreased the efficiency by an average of 18% in five subjects. This further deterioration in comparison with that obtained with the pursuit pendulum test was due to the continued application necessary over a period of 5 minutes, the subjects, under the influence of alcohol, being unable to brace themselves sufficiently for this period to maintain something approaching their pre-alcohol performance.

The work of the authorities quoted indicates clearly that, even with relatively small doses of alcohol, there is a deterioration in the efficiency of the neuro-muscular mechanisms examined. The effect tends to be most pronounced in co-ordinated actions which require continuous application.

(c) Tolerance.

As with many other drugs the human organism is capable of developing a relatively high tolerance to alcohol. It is a well known fact that the hardened drinker can tolerate much larger doses than the neophyte. In addition to acquired tolerance account has to be taken of natural or inherent tolerance. Because of varying degrees of inherent tolerance, in the absence of any alcoholic history, it is quite impossible to forecast what effect a given dose of alcohol will have on an individual. According to Soltau (1) Newman has found in experiments on dogs that, apart from any difference due to the rate of absorption, individual dogs showed a certain divergence in behaviour at similar

(1) Ref. Soltau 40.

blood-alcohol levels, indicating some degree of difference in inherent tolerance to alcohol. He noted also that in dogs which had been habituated to alcohol, although there was no significant variation in the rate of alcohol metabolism, the degree of drunkenness present at a given blood alcohol level showed a consistent and marked decrease compared with those who were not habituated. This acquired tolerance was lost after some months of abstinence. Soltau postulates a slower rate of absorption in the human addict as the most likely explanation of this phenomenon, though he also allows for other factors such as the development of an anti-body in the blood, and decreased permeability of the cell membranes and neurons. The same author quotes Marinesco to the effect that in vago-tonics meningeal permeability is less, so that alcohol penetrates from the blood into the cerebro-spinal fluid in smaller quantities than in sympathetico-tonics, the blood alcohol concentrations being equal.

2. <u>The Effect of Alcohol on Unskilled Work</u>.

The Medical Research Council have reviewed in their Report (1) many experiments bearing on this subject. In their opinion the results of Rivers, and Oserctzkowsky and Kraepelin, are inconclusive. Hellsten made an extensive series of ergographic experiments. He found in one subject that doses of 25 to 50 cc. of alcohol, given in appropriate dilution with water five to ten minutes before the ergo-

(1) Ref. Report of M.R.C. 2.

graphic record began, produced no clear and unequivocal effect on the record. When the dose was 80 cc. - equivalent to 5 to 6 ounces of whisky or more than 3 pints of beer - there ensued, after a slight and brief improvement in the record, a marked decrease in the recorded muscular work. When this dose preceded the test by half an hour, the decrease observed amounted to 20% of the normal performance. The decrease was 17% when the dose preceded the test by one hour, and 11% when two hours elapsed before taking the reading.

Dürig (2) observed the effect of alcohol on a hill climber. The ascent and the route taken and all other factors were kept constant. The climber had 30 cc. of alcohol in 150 cc. of water (i.e. as much alcohol as is contained in 2 ounces of whisky or 1¼ pints of beer) with his breakfast before starting. The walker felt no difference in his condition but under the influence of alcohol the distance, and ascent per minute, were 12 to 14% less than when he had no alcohol. However, the energy expended was greater. This deterioration was attributed by Dürig to an impairment of skill, the dose of 30 cc. of alcohol abolishing the effect of previous training.

It is indicated, though the volume of work on this aspect of the subject is not great, that a relatively small dose of alcohol exerts little influence on the performance of work of a simple character not demanding

(2) Ref. Dürig 13.

precision in a subject accustomed to its moderate use.

3. <u>The Effect of Alcohol on Skill of Performance.</u>

If, based on a review of the experience of a number of workers, it be true, as postulated above, that alcohol interferes with reflexes and voluntary neuro-muscular processes, then we ought to find objective evidence of this in a diminution of skill in the alcoholic subject.

The narcosis produced in the early stages of alcoholic intoxication effects changes which are easily observable. "The drinker begins to show a certain clumsiness of behaviour. If he is self-observant he notices that he is liable to make ill-adjusted movements, when he sets down his glass it makes a more violent contact with the table than he intended, on rising he may stumble against a chair perhaps upsetting it; on lighting a cigarette he may break the match which he essays to strike, in speaking he may slur a word or drop an 'h'. Each little mishap will at first be quickly rectified, for each one may evoke the power, possessed in some degree by all and to a wonderful degree by many men, of temporarily correcting by an effort of concentration or self-control the paralysing effects of the drug". (1).

The external evidences of alcoholic intoxication above described can be measured in various ways, and, where no such gross clinical manifestations are obvious, the effects of alcohol may still be detected by deviation from

(1) Ref. Report of M.R.C. 3.

normal performance in skilled and semi-skilled tasks. Dodge and Benedict (2) concluded that the effect of alcohol on the co-ordination processes varied directly with the dose, came closest to the total average of all tests, covered the most general characteristics of the alcohol effect, and came nearest to being a measure of the individual's susceptibility to alcohol. However, the co-ordination processes which they measured as indices of the effect of alcohol were considered primarily from the standpoint of speed as the records did not lend themselves well to a determination of the accuracy of co-ordination. Using typewriting as a test this objection can be overcome, and not only the speed of the performance but also its accuracy can be measured.

Miles (3) made typewriting experiments using two doses of alcohol - 30 cc. and 45 cc. He found that there was a slight decrease in the speed of typewriting, particularly in the first two hours following the ingestion of alcohol, and that the larger the dose the more marked the effect. As regards accuracy, his results showed that the effect upon the percentage error made in typewriting was very marked, the increase being from 50 to 100% in the two hour interval following ingestion, and usually 25 to 40% in the interval from two to three and a half hours. The larger dose resulted in almost twice as many errors as the smaller dose. A high grade of skill in any

(2) Ref. Dodge and Benedict 12. (3) Ref. Miles 33.

motor co-ordination is in general associated with a smooth even flow of performance. For this reason the variability in the speed of typewriting is one way of measuring the excellence of the work. Miles found that during the period from $1\frac{1}{2}$ to 2 hours after taking the alcohol there was an increased variability in the speed of typewriting. Further analysis of the results showed that the number of strokes per second on the typewriter was slightly reduced after alcohol. The even progress of the writing was apparently much more disturbed than the average speed. This was determined by the co-efficients of variability of the speed of writing successive lines in each typewriting task, and by the smoothness of the performance which seems much disturbed by alcohol. The latter disturbance was exhibited by a large increase in the amount of time when the subjects' typewriting processes were confused and blocked so that he made no strokes whatever. It is evident that the typewriting, viewed from every angle, suffers strikingly in legibility as a result of the ingestion of alcohol.

A large body of work on similar lines was carried out by Vernon (4). He reports that both Rivers and Frankfurther noted a decrease in speed and an increase in errors in typing done under the influence of 20 to 40 cc. of alcohol. He had a similar experience himself making due allowance for certain variations in efficiency according to the time of day at which the work was done. One

(4) Ref. Vernon 48.

very important observation made by Vernon was that when he first began to perform a test typing the rate of execution was a good deal slower than later in the session. This initial clumsiness passed off in a minute or two under normal circumstances, but the corresponding effect noticed to a greater degree after alcohol lasted longer. This conclusion, if established by subsequent observations, is one of great practical importance with reference to the causation of industrial accidents, for it means that a workman who starts work under the influence of a certain amount of alcohol would have, at the outset, a special liability to make errors in his co-ordinated movements, and would be specially liable to meet with an accident or to spoil his work.

Vernon carried out further experiments to test the previously advanced claim that though moderate doses of alcohol had very little effect on the performance of simple muscular acts requiring no skill, they distinctly impaired the performance of skilled tasks. For this purpose he used the "target" method. On squared paper, preferably ruled in millimetres, rows of ten ink dots were made at a distance of two centimetres or more apart. The paper was pinned on a nearly vertical drawing board at such a level that the uppermost spots were at shoulder height. The subject stood facing the "target" and at such a distance that he could just reach and prick the paper with a sharp instrument held in his hand at arm's length. Before each stroke the operator's hand rested on his chest and returned there before the next attempt. The pricking was done at the rate of 20 spots in 50 to 60 seconds, and the distance of each prick from its spot was measured. Each series of 20 attempts was then averaged. Using this method Vernon discovered that whilst the consumption of 30 cc. of alcohol increased the "target" pricking error by only 12%, 37.5 cc. increased it 43% or more than three times as much. With equal increments of 7.5 cc. to the quantity of alcohol consumed the error increased at the same rapid rate. He concluded from these figures that above a certain minimum the adverse influence of alcohol on neuro-muscular co-ordination varies in arithmetical progression with the quantity taken.

Further evidence of the disturbing effect of alcohol on skilled movements is provided by Rivers in his work with the ergograph (5). He observed that though 40 cc. of alcohol did not influence the ergograph records much the control of movement did not appear to be so good, and the execution of the movement tended to be slower than usual. His evidence for this is "In the normal condition of the subject experimented with the two minutes allowed him between successive ergograms for taking the customary readings, and for making the necessary adjustments of the ergograph, were ample for his doing so: but on the 40 cc. alcohol days the period of 2 minutes was hardly long enough

(5) Ref. Report of M.R.C. 2.

for him to do what was necessary, although the time it took him seemed to him no longer than usual. This was so striking that the subject was at first inclined to believe his watch was in error, for it seemed to him that he had been carrying out his usual tasks at the normal speed. Several small accidents happened on days on which the dose of alcohol was 40 cc. and these were probably the result of awkwardness in adjusting the apparatus. Some of the intervals (between the actual spells of exercise at the ergograph) were occupied by the subject in drawing lines for tabular purposes, or in pasting ergograms in a book, and these operations were found afterwards to have been done roughly or irregularly on the 40 cc. days".

The apparatus used by McDougall and Smith (6) in their experiments was a dotting machine. It is essentially "a mechanical device whereby a continuous band of paper tape about one inch wide is drawn behind an opening or window in the top of the desk by a weight-driven clockwork movement". Along the width of the band small red circles are distributed in as irregular a manner as possible but at equal intervals. The test consists in marking the red circles with a stylograph pen as they pass before the subject's field of vision. They gave their subjects 10 to 35 ccs. of absolute alcohol mixed with three parts of water. With doses of 15, 20 and 25 ccs. there was an increase in the number of errors one hour after taking the alcohol to

(6) Ref. McDougall and Smith 29.

the extent of 42%, 39% and 113% respectively. After these doses there was in the majority of cases a marked loss of accuracy and of control. A common subjective effect was the pleasant conviction that the dotting was very good. They also observed that the weaker the solution the less marked the effect.

From the point of view of the public as a whole perhaps the most important aspect of the subject is any possible decrease in skill in motor driving that may follow indulgence in alcohol. Driving a mechanically propelled vehicle might be classed as a semi-skilled operation, and certainly the influence of alcohol on its performance would, in the light of the experiments cited above, be more marked than on ordinary unskilled manual work. Furthermore one would expect that doses of alcohol insufficient to produce clinical effects might decrease driving efficiency.

Vernon (7) used an artificial "motor driving" apparatus in his enquiries into this problem. He found that after consuming 30 cc. of absolute alcohol subjects drove more quickly but more erratically, tending to drive in rushes and their driving as tested on the apparatus was more inaccurate. Taking the 20 subjects together it was found that in some instances 7 of them had their driving time reduced 10 to 20% by drinking alcohol and 4 others had it reduced 21% or more. The effect is therefore sub-

(7) Ref. Vernon 49.

stantial in some persons and it is possible that at particular times after drinking the most effective.- though still moderate - quantities of alcohol, it is still more substantial than those figures suggest. A few of the subjects were convinced that they drove better after alcohol than before it, but their records proved the contrary. The fact that moderate quantities of alcohol tend to make most drivers accelerate their rate of driving and that more often than not this tendency is unrecognised by them is of direct practical importance. These experiments emphasize the adverse effects of alcohol on performance. Other experiments have revealed not only an impairment of attention to signals and environment but slower responses of eyes, hands and feet. The effects vary according to the kind of alcoholic drink, the individual, and the degree of his previous habituation to alcohol, apart from its strength. Nothing indeed is more striking or more common to the many researches into the mental effects of alcohol than the wide individual difference revealed in these effects. It is generally accepted that one cannot expect perfect correlation between the dose of any drug and the effect which it produces. In the case of alcohol the limit of normal biological variation is set at 10 to 15% (8).

The experimental work reviewed above indicates that the performance of acts requiring skill tends to be tempor-

(8) Ref. Muchlberger 34.

arily impaired after a dose of alcohol of about 30 ccs. This specially applies to the speed and nicety of the required act's performance. It seems therefore permissible to suppose that the greater the precisional delicacy and alertness demanded in a muscular act, and the greater its degree of difficulty, e.g., by reason of novelty to the performer, the more liable will the act be to show impairment under the influence of alcohol, and, within limits, the smaller will be the dose of alcohol which may impair the act. Reliable evidence that alcohol improves, in normal circumstances, the efficient performance of any muscular act, skilled or unskilled, seems at present to be altogether lacking.

Amongst the earliest mental changes produced by alcohol is the development of euphoria. This leads many persons to assert that they drive better after having a few drinks. The driving of the car may be more rapid and spectacular, obstructions may be missed by inches, difficult positions, which would not have been developed had no alcohol been taken, may be navigated successfully, the driver being free from all anxiety by virtue of his euphoria. Some day the spectacular risks end in disaster butthe driver in his false mental state does not think he is to blame. The state of euphoria of the slightly alcoholic is attended by lessened self-criticism, sense of responsibility, concentration, and sense of anticipation.

From the above review it therefore becomes clear that there is a very great danger arising on the roads today from drivers taking alcohol in amounts far short of those necessary to produce the obvious incapacity which is dealt with by the Law. That a person who has taken a small amount of alcohol, may drive quite well for a time in favourable circumstances, is no proof that his concentration will be maintained nor that he will deal effectively with an emergency should one arise. In this connection it is apparent that the dangerous driver is not the "dead drunk" who is found in his car asleep at the wheel, but is rather the one who can still operate the vehicle but less ably than normal, who is less cautious, and less able to meet an unexpected situation with sufficient speed.

4. <u>The Effect of Fatigue on Skill of Execution.</u>

It is generally accepted that, as the day progresses and the products of metabolism accumulate in the tissue cells, efficiency and speed of performance will decrease, and as a corollary that reaction times will increase.

Vernon (1) found in his experiments on typing that the time required for the test typing increased slightly between 9.10 a.m. and 6.47 p.m. while the number of mistakes diminished. The improvement in neuro-muscular co-ordination indicated by his data is well known in other kinds of manual work and it occurs chiefly during the first

(1) Ref. Vernon 48.

few hours of the morning. This improvement gradually becomes neutralised, and eventually overpowered, in the course of the day by fatigue effects. The influence of fatigue is shown in Vernon's figures by the fact that typing done in the evening was slower and showed more mistakes than that done up to 6.47 p.m.

Using the "dotting" machine McDougall and Smith (2) made some very interesting observations on the effects of fatigue on neuro-muscular co-ordination. The initial effect of fatigue due to loss of sleep was to improve performance for about three days. This was followed up by a second phase of about 13 days duration when the errors gradually rose to a number considerably higher than normal, followed by a somewhat irregular return to normal. As a result of one night with only 1½ hours sleep the errors in the dotting fell from an average of 52 for the preceding fortnight to 38. Half an hour after having taken 15 cc. of alcohol the errors rose to 137, a number greater than any resulting from fatigue during the cycle. Three days later the alcohol increased the errors from 45 to 113. Towards the end of the cycle, however, when the graph showed a tendency to approach the normal the alcohol reaction is different for, on the 13th day, the errors in the dotting being 95 the effect of alcohol was to reduce the errors in dotting to 66, with a similar result the day following. This phenomenon was not due to habituation

(2) Ref. McDougall and Smith 29.

because the normal effect of alcohol in increasing the number of errors was found after the fatigue cycle had passed and the number of errors had reached normal.

Alcohol seems thus to have a different effect according to the stage of recovery from fatigue. It has been shown that after considerable loss of sleep, tested by the power to give sustained voluntary attention, there is a stage when fatigue acts as a stimulant followed by a stage charactерised by deterioration in the powers tested. This second phase is again divided into two parts (a) the stage when alcohol has the same effect as on the normal state, i.e., depresses the higher powers, and (b) the stage when it seems to act as a stimulant. Unfortunately these experiments do not determine what exactly is the degree of fatigue which can be neutralised by alcohol, for, at the time when fatigue is most acute, the alcohol effect is the usual one.

From this work it is clear that fatigue may be an important factor in any experiments on reaction times. Furthermore, if the method to be described below is to be used in actual practice, the influence of fatigue must either be allowed for or adequate reasons found for this omission. Most offenders arrested as incapable of having proper control of a car due to alcohol commit their breach of the law in the evening or the early hours of the morning. It is therefore, essential if late in the day the abnormal reading is taken, to know what proportion, if any, has to be allowed for the normal effects of fatigue.

5. <u>Reaction Times</u>

(a) <u>Alcohol and Reaction Times.</u>

A considerable volume of work has been done on the subject of reaction times, using many different types of apparatus of all degrees of complexity, and in the course of the study of many problems apart from that of alcoholic intoxication.

The first series of experiments on the effect of alcohol on reaction times was made by Exner (1) who found that alcohol increased the reaction time. Dietl and Von Vintschgau (2) made a comparative study of the effects of morphine, coffee, and wine, and concluded that alcohol decreased the reaction time. Kraepelin (3) experimented with amyl nitrite, ether, chloroform and alcohol, and found that moderate doses of alcohol differed from ether and chloroform by first decreasing and then increasing, the reaction time; while Warren (4) studied the effect of alcohol on the simple reaction and noted no general effect of any definiteness.

In his work Varé (5) used the d'Arsonval clock to measure the effects of alcohol on simple reactions to light and sound, and on reactions with choice to light. He recorded 35 readings at each session and then discarded

(1) Ref. Exner 14.
(2) Ref. Dietl and Von Vintschgau 11.
(3) Ref. Kraepelin 28.
(4) Ref. Warren 50.
(5) Ref. Varé 47.

the five longest readings as likely to be due to some external accidental factor. Only three experimental results are quoted and these show an increase in all three reactions, but particularly in reactions with choice. The mean variations of the readings were also increased, demonstrating a decrease of attention after alcohol and a consequent increased variability of the results. Varé concludes, as a result of this small series of experiments, that the ingestion of alcohol acts both on the physiological and the psychological processes which constitute the reaction time, slowing them, and diminishing voluntary attention. He points out the practical importance of the observation for drivers of cars who should possess psychomotor reactions which are constant and rapid.

Zwahlen (6) studied the influence of alcohol on reaction time using the d'Arsonval apparatus. He allowed his subjects five practice readings and then recorded 35 true readings. As did Varé, he then discarded the five longest readings because they might have been prolonged by some external fortuitous circumstance. Having taken normal readings alcohol was then administered and the readings repeated. Three experimental results are quoted to show that the ingestion of between 100 and 300 ccs. of 50% alcohol lengthens the reaction time to both light and sound, and that the mean variation is also increased.

(6) Zwahlen 51.

The apparatus used by Jonnard and Maire (7) in their work on the effect of tobacco, coffee and alcohol on reaction time consisted in two d'Arsonval clocks in circuit. One clock is started by the operator and a bell rings. This serves as a warning to the subject and the reading on it provides a record of the length of the subject's attention. When the second clock starts the subject of the experiment must press a key to stop it as soon as he is conscious that the hand is in motion. Using 20 cc. of rum at 50% diluted in 75 ccs. of tepid water these workers found the reaction time increased from 16.6 to 18.6 hundredths of a second. When half that amount of alcohol diluted to the same volume was given they again recorded a minute increase in the reaction time. The obvious criticism of these results is that the number of subjects tested was very small and the increase in reaction time relatively insignificant. It is difficult to conceive how 10 ccs. of rum diluted in 75 ccs. of water could have produced any effect in five or ten minutes, and the increase noted is so small that it might well have arisen by chance. Very large numbers of experiments on the same lines would have to be performed to bear out the conclusions advanced but the change recorded, whether it was due to the alcohol or not, was in the same direction as that noted by most modern workers. Jonnard and Maire repeated their experiments using 250 cc. of strong champagne

(7) Ref. Jonnard and Maire 26.

instead of rum, the two solutions containing the same proportion of alcohol. They used two subjects for the experiments and found that the champagne produced a totally different action on the psycho-motor reactions compared with rum. They reported that the time was slightly improved - a matter of .5 of a hundredth of a second - and that this improvement passed off in twenty minutes. The same criticisms can be levelled at these two experiments also, and this is recognised by the authors.

Heise and Halporn (8) devised a rather elaborate, and somewhat impractical, apparatus for observing and measuring the effects of alcohol on the skill of motor drivers, and on their reaction time to sound. A motor car was adapted so that firing a gun would give the signal to apply the brakes, and this in turn would fire another gun. A knowledge of the speed of the car, and the distance apart of the bullet marks on the road, furnished a means of measuring the reaction time. In addition, the car had to be driven along a curved lane marked by corrugated packing cases whose position could be altered without notice, thus making quick decisions necessary on the part of the driver, and preventing him from anticipating the signal to stop. Under the influence of alcohol the subjects made mistakes in driving, such as colliding with the boxes and firing the gun on the brake pedal at the wrong time. These experiments demonstrated a definite slowing and an increase in variability of the reaction time.

(8) Ref. Heise and Halporn 21.

Newman and Fletcher (9) used a laboratory car with a moving road scene to test the accuracy of driving, and they also measured the reaction times of the subjects for braking on a given signal. They found no significant correlation between loss of efficiency from alcoholic indulgence and the factors of age, sex, driving experience, or drinking habits. Several of the subjects made the statement prior to the test, that, in their opinion, their driving skill was somewhat improved by moderate doses of alcohol, and a few felt that they did better in the test after drinking. It is of interest to note, therefore, that in no case was the performance in all the tests improved after alcohol. This experience is in keeping with that of Vernon (10) recorded above. De Silva (11) designed an apparatus which duplicated exactly the arrangement of the controls in a 1934 Ford V-8 car. A regulation red, amber and green traffic signal was placed before the subject who was informed that the apparatus would determine how fast he could lift his foot off the accelerator and depress the brake pedal when the red light flashed. He was told to put his right foot on the accelerator when ready. Pressing on the accelerator started the cam of a motor selector switch which turned on the green light. Two seconds later the green light was replaced by amber and, at a variable interval thereafter, the red light was

(9) Ref. Newman and Fletcher 35. (10) Ref. Vernon 49.

(11) Ref. De Silva 10.

switched on. When the red light appeared the subject removed his foot from the accelerator and depressed the brake pedal as quickly as possible. The time taken to do this was measured in hundredths of a second. He found that, as a result of testing 4,000 people, the average reaction time is about 0.44 sec. The times varied from 0.24 sec. up to 1.00 sec. Quickness in this test was found to be an inborn potential factor and was not improved very much by driving experience. By an improvement in the apparatus De Silva was able to estimate the time taken by the subject to see the signal and start to lift his foot. He found that this "psychological reaction time" is about 55% of the total braking reaction time defined above. For example, if the braking reaction time is 0.50 secs. it takes the subject 0.27 secs. to see the signal and start his foot, and 0.23 secs. to move the foot from the accelerator to the brake.

The Industrial Health Research Board (12) report that from a test of brake reaction times an average of half a second is required to remove the foot from one pedal (accelerator) and place it on another (foot brake) at a sudden signal - that is even without the mental processes needed in practice to decide what it is best to do. With this reaction time in the driver of a car travelling at 30 miles per hour the car would move 22 feet before the brake was even applied. There is no direct evidence that those with a slow reaction time have an undue number of

(12) Ref. Ind. Health Research Board Report 1.

accidents but it seems likely that they do. The figure quoted in this report corresponds closely to that of 0.44 sec. advanced by De Silva.

Working in the Massachusetts Institute of Technology, Frank (13) devised an appliance for measuring the speed of response of men and women to visual and auditory stimuli. The device was used to measure the time interval between the instant of application of the brake in one car, and the instant the operator in the car following noted the act and applied his brakes. The tests showed that the time consumed averages about 0.6 sec. for men and 0.8 sec. for women if the cars are equipped with spot lights. If there are no spot lights the time is twice as long.

The times obtained in traffic studies are much longer than reaction times obtained when keys are pressed by individuals in response to a warning light or sound. Reaction times vary with the apparatus used and with the complexity and nature of the experimental conditions. Rutherford (14) reported the reaction time to light in man as from 0.20 secs. to 0.22 secs. Bellis (15) gave 0.22 secs. for males and 0.26 secs. for females of the same age in response to a simple light stimulus. Cheney (16) found that the average normal reaction time for young adults was 0.38 secs. for men and 0.50 secs. for women. Baxter and

(13) Ref. Frank 18.
(14) Ref. Rutherford 38.
(15) Ref. Bellis 5.
(16) Ref. Cheney 7.

Travis (17) as a result of a review of previous work found that the results varied from 0.150 secs. to 0.200 secs. for visual stimuli, and from 0.120 secs. to 0.160 secs. for auditory stimuli in different papers examined.

It is quite obvious from the above review that the reaction time obtained depends on the apparatus used, and on the conditions under which the reading is taken. The effect of any given factor on this figure must therefore be interpreted only in reference to the apparatus used.

The general trend in most of the modern work is that alcohol produces an increase in the reaction time, depending of course on the dose, and that the drug has an adverse effect on the efficiency of drivers of motor cars.

(b) <u>The Effect of Practice on Reaction Time.</u>

In attempting to measure alterations in any human function or faculty, due to some particular abnormal influence one has to try to establish a normal which is influenced by as few uncontrollable factors as possible. The measurement of the reaction time to any stimulus must involve the manipulation of some sort of apparatus by the subject, and his particular part in the experiment may be either very simple or extraordinarily complex. On the first occasion, at least, on which he is subjected to test one would imagine that the subject would find his part

(17) Ref. Baxter and Travis 4.

in the programme strange, even though the act he has to perform is one to which he is accustomed, because of the mere strangeness of his surroundings and consciousness of observation or measurement alone. For this reason one would naturally expect that practice would play a very prominent and important part, and the more complex the manoeuvre the greater its effect, and the longer the period of training necessary to eliminate it as a factor in the result.

Dodge and Benedict (1) in their extensive study of the psychological effects of alcohol decided to omit reaction times of the simple type from their series of observations "because of the necessity of extensive preliminary practice before the reaction times have any real significance, partly because of the uncontrollable interplay of interest and attention and the easy contamination of results by arbitrary, conscious control and partly because the best analyses of the various processes show such variability of the possible subjective attitude to the experiment that one can be sure of similar experimental conditions only in subjects of the most careful training". They preferred to utilise practical reactions involving complex arcs which are thoroughly practised and comparable in different individuals such as the eye reactions to which reference has already been made.

In his experiments Miles (2) took elaborate precautions in the matter of controls to establish a normal before

(1) Ref. Dodge and Benedict 12. (2) Ref. Miles 33.

attributing any effect observed after giving alcohol, to the alcohol itself. He advocated the taking of one or more control measurements before the alcohol experiment on any particular day. The preliminary data serve as normal for the day and are contrasted with the performance after alcohol, but, in Miles' opinion, do not form by themselves an adequate base-line for estimating the effect of alcohol. He maintained that it may easily happen that the performance, after the preliminary period of measurement, normally becomes improved, or on the other hand may be poorer. He made blank or control experiments in which the preliminary periods, the dosage (without alcohol), the duration, and the general conditions were the same as those obtaining in the alcohol sessions. Miles made two preliminary sets of readings, then gave a control dose followed by four more sets of readings one day, and next day repeated all this substituting alcohol for the control dose. He then utilised the pre-control, post-control and pre-alcohol readings to establish his normal against which the post-alcohol readings were compared. In his opinion practice is essential, and he even goes so far as to advocate preliminary alcohol experiments before actual readings are counted in assessing the results.

Jonnard and Maire (3) allowed practice for the subject to attain his established normal reaction time. Further reference will be made to this matter when considering

(3) Ref. Jonnard and Maire 26.

daily variability in reaction times.

Cheney (4) in studying the pharmacological effects of caffeine and coffee allowed his subjects ten days practice in order to attain their established normal reaction time. He found that no further improvement ensued after three days practice and attributed any change in the time recorded after this preliminary training to the caffeine or coffee.

Zwahlen (5) working with the d'Arsonval clock, allowed only five preliminary practice attempts before recording results.

The other authors whose work has been reviewed in the earlier sections of this thesis, do not mention specifically the precautions, if any, which they took to eliminate the effects of practice from their results. I hope later in this thesis to be able to demonstrate, by statistical analysis of a relatively extensive series of observations, that from the practical point of view it is unnecessary to allow for the effect of practice.

(c) <u>Daily and Diurnal Changes in Reaction Times</u>.

The human organism is subject to continual change, not only from day to day, but at different times in the same day. This may be due to the atmospheric temperature and humidity, body temperature, the state of the alimentary canal and the bladder, external influences producing psychological changes and responsible for a

(4) Ref. Cheney 8. (5) Ref. Zwahlen 51.

feeling of well-being or the reverse, and probably many other factors. These variations were noted by Dodge and Benedict (1) by Miles (2) and also by Zwahlen (3).

The effect of body temperature on reaction time was studied by Kleitman, Titelbaum and Feiveson (4). Using a Hipp chronoscope they took readings from five subjects at two hourly intervals from 9.0 a.m. to 9.0 p.m. The results show that there is a diurnal variation in simple, and with choice reaction times. The time is shortest in the early afternoon and is longest in the early morning and late evening. They noticed that this alteration in the reaction time corresponded, in some cases at least, to the diurnal temperature curve, which they found to have its peak at from 1.0 p.m. to 3.0 p.m. In short, during the day the higher the body temperature the quicker the reaction and vice versa. The readings of one of the subjects quoted by the authors are shewn below:-

			Reaction Times	
Subject	Hour of Day	Oral Temp. °F.	Visual 0	Auditory 0
S. T. 1.	9 a.m.	97.94	155.2	144.9
	11 a.m.	98.18	144.6	136.3
	1 p.m.	98.34	139.9	134.3
	3 p.m.	98.60	143.3	137.0
	5 p.m.	98,58	149.6	141.5
	7 p.m.	98.38	150.4	138.0
	9 p.m.	97,96	161.6	157.3

(0 = Thousandth of a second).

From this work it appears that there is a fairly

(1) Ref. Dodge and Benedict 12.
(2) Ref. Miles 33.
(3) Ref. Zwahlen 51.
(4) Ref. Kleitman, Titelbaum and Feiveson 27.

good relationship between body temperature and reaction time regardless of the time of the day. This indicates that there is probably no diurnal reaction time curve independent of the temperature. On the contrary it would appear that it is always dependent upon the body temperature which, whenever it become changed, is accompanied by a change in reaction time in the opposite direction. The relationship between temperature and reaction time is brought out by averaging together the reaction times for tests made when the temperatures were the same, regardless of the time of the day. This shows that in general the higher the body temperature the shorter the reaction time. Artificial postural changes in the body temperature tended to confirm the above finding. While body temperature may play an important part in the diurnal changes in the reaction time, I doubt whether the other factors mentioned above can be entirely ignored.

These results, while academically interesting, are of little importance in connection with the subject of this thesis, because the differences in the readings are so small. In the case of subject S.T.(1) for example, the difference between the greatest and least reading for simple visual reaction time is 2.17 hundredths of a second. Whether a difference of this order is likely to lead to a false conclusion regarding sobriety in an actual case will be considered below.

Jonnard and Maire (5) and Cheney (6) succeeded in reaching an "established normal reaction time" in their subjects as a result of practice. If this could be done it would be a great advantage in experimental work on the influence of any additional extraneous factor on the reaction time. In effect it would mean that a normal subject, after sufficient practice, would always record the same time and any alteration would be attributed to the additional factor under investigation. I therefore resolved to enquire into this aspect of the problem and my results will be considered at a later stage.

(d) The Relationship between Age and Reaction Time.

If one is attempting to establish the normal limits of the reaction time for the purpose of detecting abnormality in subjects of unknown normal reaction time, where the question of alcoholic intoxication arises, it is obviously important to enquire into the effect of age on this quantity. If age is an important factor then due allowance would have to be made for it in assessing any case.

Bellis (1) studied 150 individuals sampled at random and varying in age from four to sixty years. The results were considered in age groups as shown in Table 1 and 2 below:-

(5) Ref. Jonnard and Maire 26.
(6) Ref. Cheney 8.
(1) Ref. Bellis 5.

TABLE 1.

Group	Age Limits	Average Age Male	Average Age Female
A	4 - 10	7.3	5.4
B	11 - 20	18.0	16.3
C	21 - 30	24.5	23.5
D	31 - 40	36.1	35.8
E	41 - 50	44.8	45.5
F	51 - 60	55.1	58.4

TABLE 2.

	MALES				FEMALES			
Group	Light	S.D.	Sound	S.D.	Light	S.D.	Sound	S.D.
A	.34	.1070	.34	.0928	.62	.1644	.59	.1890
B	.24	.0400	.23	.0409	.32	.0340	.31	.0407
C	.22	.0331	.19	.0338	.26	.0192	.20	.0736
D	.26	.0465	.24	.0141	.34	.0378	.30	.1139
E	.27	.0266	.25	.0468	.36	.0342	.30	.0372
F	.38	.0574	.37	.0806	.44	.0721	.42	.0842

S.D.- Standard Deviation.

Each group contained 20 individuals, except Group F which had 10. Half the subjects were males and half females. Bellis found that on an average males always responded to light and sound stimuli more quickly than females, especially in childhood and late maturity, the figures closely approximating each other in the third decade. The shortest times were elicited between the ages of 21 and 30 (Group C) with decrements approaching from earlier and later age groups.

These figures show that in the case of the 75 male subjects examined there is a 73% increase in reaction time to light, and a 95% increase in the reaction time to sound for these in Group F over those in Group C. In the opinion of Bellis it is probable that the greatly increased number of accidents happening to old people may, to some extent at least, be due to their increased reaction time.

Cheney (2) agrees with Bellis in his conclusion that reaction time increases with age.

Goodenough (3) used the Miles reaction board to study the development of the reactive processes from childhood to maturity. He was able to determine the simple reaction time with a satisfactory degree of reliability in children as young as $3\frac{1}{2}$ years. This finding is important as it forms one justification for the utilising of this test practically on the drivers of motor cars. He found that the developmental changes in variability are much more marked than the improvement in average speed. This author studied data collected by Miles and found that they suggested a similar trend during the years of mental decline. Newman and Fletcher (4) established that there is no significant correlation between loss of efficiency due to alcohol and the factors of age and sex.

The conclusions reached by Newman and Fletcher seem at first sight to be incompatible with those of Bellis, Cheney and Goodenough. However, while it may undoubtedly be true that there is a definite relationship between age

(2) Ref. Cheney 8. (3) Ref. Goodenough 19. (4) Ref. Newman & Fletcher 35

and reaction time, it does not necessarily follow that the co-efficient of correlation is sufficiently high to make the relationship of practical importance when an additional factor such as a dose of alcohol is introduced into the picture. One would in fact expect from ordinary observation that in advanced age the reaction time would be increased but what really matters from the point of view of this thesis, and in actual practice, is whether that increase is such as to necessitate allowance being made for it in each case of drunkenness while in charge of a motor car.

(e) The Relationship between Intelligence and Reaction Time.

If the reaction time is proportionate to the intelligence then it is unsuitable as a test to be applied to all grades and classes of the community, unless steps are taken to obtain the subject's normal reading for comparison with the suspect one. The fact that Goodenough (1) was able to obtain reliable readings from children of 3½ years surely indicates that it ought to be safe from this aspect to apply the test to drivers of motor cars. In the case of his child subjects he found, in agreement with the result for adults, that there is only a slight relationship between scores on intelligence tests which do not involve speed and the speed of a simple reaction. The correlations between speed of reaction and performance tests in which speed is a factor, although not high, were positive at all

(1) Ref. Goodenough 19.

ages. Goodenough found no apparent relationship between speed of reaction and socio-economic status. He concludes that, in any group of individuals selected at random from a reasonably homogeneous population, the relationship between intelligence and reaction time is very slight.

One would expect, on general principles, that if the intelligence tests involve speed, then there would be some relationship between speed of reaction and mental ability. By observing an individual one can form a general impression of his tempo. He may be obviously average like most people, or deliberate and slow, or again he may be very wide awake, quick to respond, and physically and mentally alert. Judged by these standards it would be expected that reaction times would fall roughly into three groups to correspond to the above classification. I have found it very difficult to forecast whether a subject will have a rapid or a slow reaction time. On occasion I have noticed that a slow stolid man had a long reaction time as expected but alternatively I have often found my prediction quite inaccurate.

Obviously if the subject is of such a low grade of intelligence that he cannot maintain his interest and attention long enough to perform the test properly, then, as concentration on the task in hand is an essential feature in recording reaction times, he would probably show a very high average reading and the standard deviation of his readings would be considerable. In such a case he is unlikely to be the driver of a motor car and therefore the question will not arise. If a child of $3\frac{1}{2}$ years can record satisfactory reaction times then surely all motor car drivers ought to be able to do the same.

6. The Effect of Food on the Absorption of Alcohol.

It is a common experience in Police Court work for the accused's representative to advance, as a mitigating circumstance in a "drunk in charge" case, that his client had had no food for many hours and that the small quantity of alcohol admittedly taken had therefore an unexpectedly serious effect on his client. It is a well known fact generally that alcohol taken on an empty stomach will produce a more toxic effect than if the same quantity is consumed with a meal. There is a considerable body of scientific work to support this contention.

Working with dogs Mellanby (1) found that a meal of bread and milk administered before the alcohol slowed down absorption and reduced the maximum blood alcohol level attained. The effect of such a meal was most marked when it was ingested less than two to three hours before the alcohol, and the longer the interval between the alcohol and the food, the smaller the effect. The clinical symptoms of intoxication were, as would be expected, greatly reduced when bread and milk was taken before the alcohol. Mellanby found that the milk is the active principle, and when added to the alcohol it acts similarly. It is the fat content of the milk that slows down absorption of alcohol.

(1) Ref. Mellanby 31.

It was found that cheese had a very slight effect, and that suet had a depressing effect on the absorption of a 20% solution but did not influence the rate of absorption of a 5% solution. This may have been due to the fact that the fat enters into a physical relation with the stronger alcohol and so inhibits absorption while with a 5% solution such a physical combination is not possible.

Mellanby also made the interesting discovery that alcohol is more rapidly absorbed if the animal has a drink of water two hours before the alcohol is taken. Two hours must be allowed for the absorption of the water or it simply dilutes the alcohol. The water stimulates the intestinal mucosa leading to rapid absorption. The times quoted do not necessarily apply to man though the experiments apply in a general way. He found that the blood alcohol level fell more rapidly if water had been previously taken, due probably to the dilution of the alcohol in the tissues by the water already absorbed. The fluid of an initial drink may act as a stimulus to the absorption of a second drink.

In his experiments on human subjects Vernon (2) found that, at the height of its influence, alcohol is about twice as active in upsetting neuro-muscular co-ordination when taken on an empty stomach as when taken with food. His experience was that after taking alcohol with a meal the maximum effect of the alcohol in each case developed

(2) Ref. Vernon 48.

very soon after the meal was completed and then gradually diminished until in the case of a fat-free meal it nearly reached normal three hours later. In the case of a fatty meal the initial effect of the alcohol was rather smaller but it did not wear off nearly so rapidly, and even $3\frac{3}{4}$ hours afterwards there was still a considerable alcohol effect. Vernon's work indicates that the more fat present in the food the slower the absorption and metabolism of the alcohol taken at the same time. Fatty food is well known to be digested more slowly than fatless food and a delay in the digestion of the meal as a whole would inevitably delay the complete absorption of the alcohol taken with it. The fat also acts in another way as it has considerable solvent power for alcohol, so a portion of the alcohol cannot be absorbed until the whole of the fat is absorbed likewise.

The influence of food on the toxic effect of alcohol depends on several factors. The food dilutes the alcohol considerably but more important than this it greatly delays its absorption. The alcohol gets well mixed with the stomach contents and is thereby prevented from coming into such frequent and intimate contact with the gastric mucous membrane as when it is taken without food. Again the mixture of food and alcohol remains much longer in the stomach than does alcohol taken alone, and it is probable that the gastric mucous membrane absorbs alcohol considerably more slowly than the intestinal mucosa. The solvent action of fat on alcohol mentioned above also plays its part.

Miles (3) and McDougall and Smith (4) have also noted the effect of food on the absorption of alcohol, and on the intensity of the clinical effects produced. The last named workers noticed that 30 cc. of alcohol taken with a meal had very little effect as far as the dotting test described above was concerned.

The stomach contents at the time of the ingestion of alcohol for experimental purposes is therefore most important, and to obtain maximum effects, and corresponding economy of material, the stomach should be empty or nearly so.

In studying the literature on the subject I have not so far been able to discover any reference to work on the effects of proximity to a meal on the reaction time alone, uncomplicated by any additional factor such as alcohol intake.

(3) Ref. Miles 33. (4) McDougall and Smith 29.

(4) <u>SUMMARY OF THE PRESENT POSITION IN REGARD TO ALCOHOL AND REACTION TIMES.</u>

1. Tests for drunkenness are numerous but none of them is conclusive. They afford no objective evidence that can be offered in court and are subject to individual interpretation.

2. Alcohol is a narcotic which acts on the synapses. It depresses the higher cerebral centres first. This depression is responsible for the so-called stimulant effect and this early manifestation of alcohol intake is not seen under experimental conditions.

3. A variable degree of tolerance to the drug is inherent and additional tolerance may be acquired.

4. <u>Effect of Alcohol on Neuro-muscular Mechanisms.</u>

   (a) Pulse rate increased due to disturbed neuro-muscular mechanism.

   (b) Decreased speed and accuracy of eye movements and reflexes with increased latency due to depression of the reflex arc.

   (c) Divergent views on the effect on the patellar tendon reflex.

   (d) Decreased speed of finger movements and facility of movement interfered with.

   (e) Uniform decrease in efficiency of eye-hand co-ordination as tested with pursuit pendulum.

(f) Decreased efficiency of continuous co-ordination as tested with pursuit meter.

<u>Conclusion</u>: It can be accepted that relatively small doses of alcohol produce a decrease in the efficiency of neuro-muscular mechanisms.

5. <u>Effect of Alcohol on Unskilled Work.</u>

A small dose of alcohol has little effect.

6. <u>Effect of Alcohol on Skilled Work.</u>

(a) Increased and prolonged initial clumsiness in skilled operations.

(b) Decreased speed and accuracy in typing.

(c) Increased errors in "target-pricking" test.

(d) Awkwardness and slowness in adjusting laboratory apparatus and in performing routine clerical work such as line drawing and pasting tracings in a book.

(e) Decreased accuracy in operating "dotting machine

(f) Alcoholic euphoria produces increased irresponsibility.

(g) Unconscious increase in speed and irregularity of driving.

<u>Conclusion</u>: Alcohol produces decreased efficiency in the performance of a skilled task.

7. <u>Effect of Fatigue on Skill of Execution.</u>

(a) Decreased speed and increased number of typing errors.

(b) Fatigue due to lack of sleep increases accuracy on the "dotting machine" for the first three days. For the next thirteen days there is a steady decrease in accuracy. Thereafter an irregular return to normal. In the later stages of the cycle alcohol increases accuracy.

<u>Conclusion</u>: Fatigue is a factor to be reckoned with in studying reaction times.

8. <u>Reaction Times.</u>

The actual figure varies with the apparatus used.

(i) <u>Effect of Alcohol on Reaction Time.</u>

(a) Reaction times increased and standard deviations of times increased, indicating increased variability due to diminished voluntary attention.

(b) Brake Reaction time increased and accuracy in car driving decreased.

(ii) <u>Effect of Practice on Reaction Time.</u>

(a) Necessity of practice stressed by some authors but no figures given.

(b) "Established Normal Reaction Time" attained by practice.

<u>Conclusion</u>: The effect of practice must be considered.

(iii) <u>Daily and Diurnal Variations in Reaction Time.</u>

(a) Daily and Diurnal variations noted.

(b) Diurnal variations proved to be due, at least in part, to variations in body temperature and the relationship is inverse.

(c) In face of daily variations the question arises of the possibility of reaching an "established normal reaction time".

<u>Conclusion</u>: The possibility of reaching an established normal reaction time must be enquired into.

(iv) <u>Relationship between age and reaction time.</u>

(a) Shortest reaction time between ages of 21 and 30 years, with gradual increase in either direction towards early childhood and old age.

(b) No significant correlation between loss of efficiency due to alcohol and age.

<u>Conclusion</u>: Any allowance necessary for age must be considered in assessing abnormal reaction times.

(v) <u>Relationship between Intelligence and Reaction Time.</u>

(a) No relationship exists between intelligence and reaction time where the intelligence test does not involve speed.

(b) When the intelligence test is a question of speed there is a positive but very low correlation between intelligence and reaction time.

(c) Children of $3\frac{1}{2}$ years can record reaction times satisfactorily.

<u>Conclusion</u>: Intelligence need not be considered with reference to increased reaction time in car drivers under the influence of alcohol.

9. <u>Effect of Food on the Absorption of Alcohol.</u>

(a) Alcohol rapidly absorbed from an empty stomach.

(b) Alcohol taken with or immediately after a meal is less rapidly absorbed but the effect clinically, though less marked, is more prolonged. A fatty meal has the most pronounced effect in this direction.

<u>Conclusion</u>: In planning any experiments with alcohol the stomach contents at the time of administration must be considered.

(5) PERSONAL OBSERVATIONS.

Having decided, as a result of a study of the work reviewed above, that the changes in the reaction time induced by alcohol could usefully be employed as an index of intoxication, particularly with reference to the drivers of motor cars, it became necessary to elaborate an experimental method and to design a suitable piece of apparatus for recording the readings.

1. Apparatus.

From a survey of previous records of reaction times it was obvious that the apparatus must be capable of recording accurately in hundredths of a second, and electrical control seemed essential, all the modern methods of measuring this function operating on this principle. My choice fell on the d'Arsonval chronoscope, and I was very fortunate in being able to borrow one of these clocks from the Central Medical Establishment of the Royal Air Force through the courtesy of Group Captain G. Struan Marshall, the Officer Commanding.

The D'Arsonval chronoscope is operated by a clockwork mechanism which is fitted with a governor to ensure constancy of speed irrespective of the tension of the spring. Though mechanically driven, the clock is electrically controlled, and this depends on two sets of electro-magnets. Fitted to the clockwork mechanism is a cork-lined clutch, which, on the completion of an 8-volt circuit, is brought into contact with a toothed wheel by the activation of one set of electro-magnets. This at once starts the hand of the clock. The clutch is disengaged by a 2-volt electro-magnet, which, when brought into play at once stops the hand. The interval elapsing between the starting and stopping of the hand can be read on the face of the clock to the nearest hundredth of a second.

As I wished to measure simple reaction times to light and sound, I therefore designed the wiring of the equipment so that either a visual, or an auditory signal, could be selected by the operator, and so that the emission of the signal, and the starting of the clock to mark that point of time, would be absolutely synchronised. One circuit therefore includes the chronoscope, a selector pear switch, the operator's switch, and the lamp and bell for emitting the signals. Part of the circuit belongs exclusively to the lamp, part to the bell, and part is common to both. An eight volt battery provides the current necessary for starting the hand of the clock, lighting the lamp, and ringing the bell. As one operating switch controls both the signal selected and the chronoscope, the movement of the hand from zero and the emission of the signal are absolutely synchronised. Selection of the appropriate circuit, according to whether a visual or auditory signal is required, is made by operating a pear

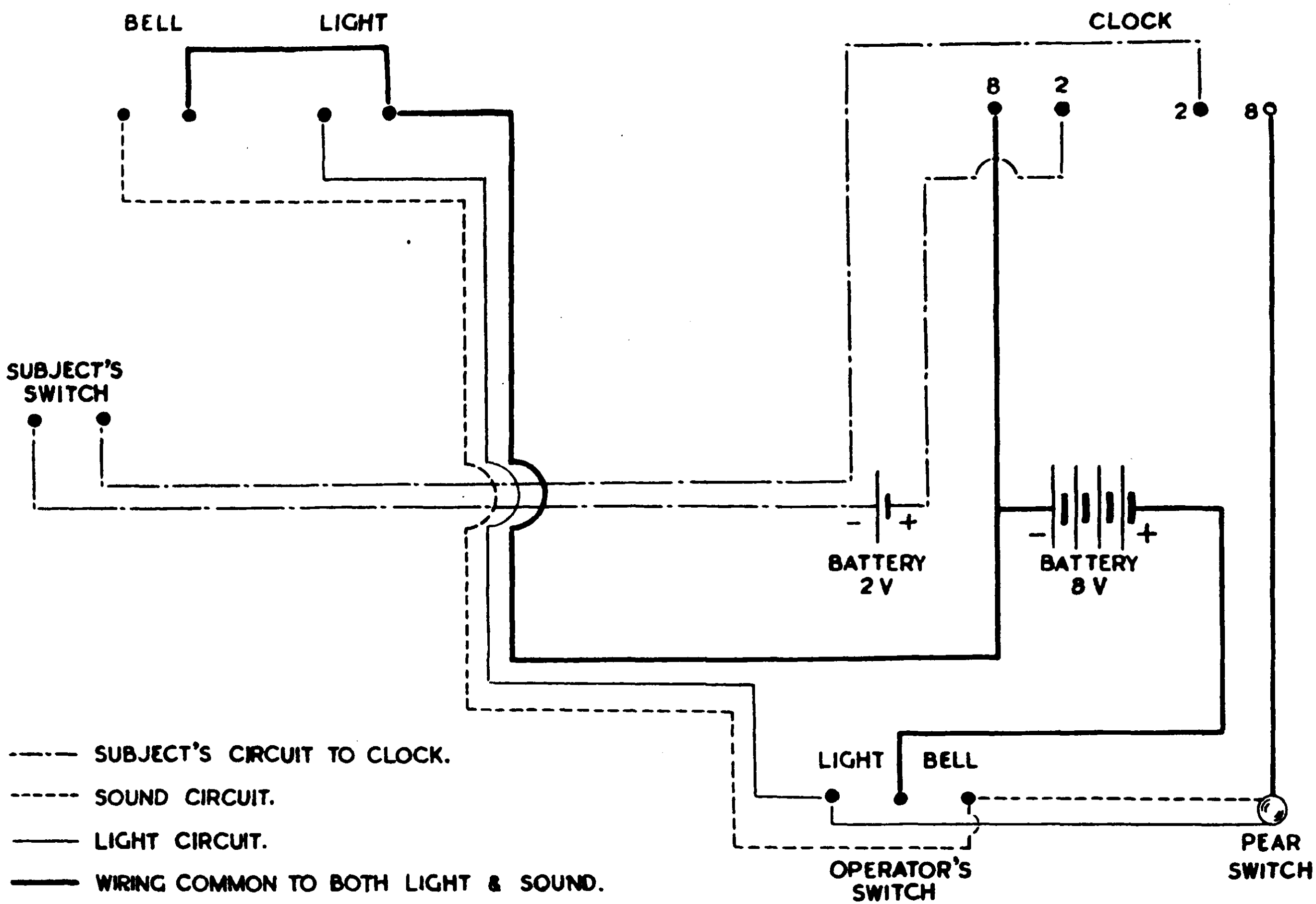


DIAGRAM OF ELECTRICAL CIRCUITS IN THE APPARATUS.

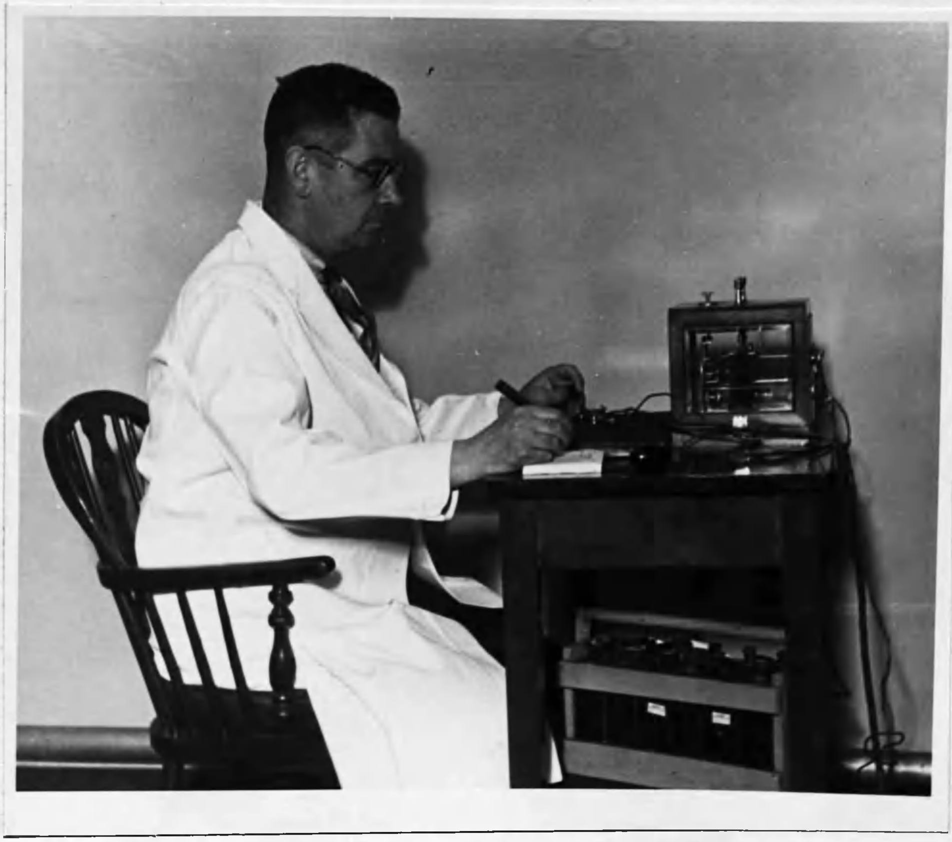
switch. There is an independent circuit to the clock including the subject's switch and a 2-volt battery. Completion of the circuit at once disengages the clutch and stops the clock. The electrical circuits involved are illustrated in the accompanying diagram.

As the examination of actual cases might conceivably have to be conducted in premises other than the laboratory where the apparatus is ordinarily housed, I decided to design the equipment so that it would be portable and capable of rapid assembly.

The apparatus as originally designed was intended to be so compact that it could be used on a small table, the operator sitting at one side and the subject at the other. The main portion of the machine consists of a wooden case thirty-six inches long by fifteen inches broad. In the centre of this box there is a hinged lid which can be erected to form a partition separating the operator from the subject. On the subject's side there is a "bell-push" attached to the base board by a length of flex so that he can hold it conveniently in the hand with the thumb resting on the button. In the centre of the upright board there is an aperture three quarters of an inch in diameter behind which the lamp is situated (Photograph 1). On the operator's side the clock stands on the base of the apparatus facing him and the control switches are easily accessible. The bell is also located on this side of the board and is of

PHOTOGRAPH
No. 1.

PHOTOGRAPH
No. 2.



the single stroke type. The battery stands on a shelf under the table in a suitable wooden carrier. This arrangement was found to be very convenient from the point of view of compactness, but it was soon discovered that certain intrinsic noises in the mechanism could not be completely damped, and, while of no significance in testing the auditory reaction time, they might have served as a warning to the subject of the imminent appearance of the visual signal. Consequently the lay-out of the equipment had to be altered.

The problem was solved by removing the clock, the observer's keys, and the battery, to a distance of about 12 yards. This was achieved by the addition of a length of flex, and mounting the observer's keys on a separate base board.

By this means the operator and subject were isolated from one another, and no extrinsic noises likely to complicate the result could possibly be heard by the subject. This modification proved very satisfactory. The fact that the clock, and the lamp and bell, are separated by a distance of 12 yards does not affect the synchronisation of the signal and the starting of the hand, because an electric current travels with the speed of light and the time taken to travel 12 yards would be quite negligible in comparison with readings taken in hundredths of a second. This modification of the original layout of the apparatus was adhered

PHOTOGRAPH
No.3.

to throughout the experiments. (Photographs 1 and 2).

This re-arrangement did not seriously affect the portability of the equipment which can be carried quite conveniently by one man (Photograph 3) and can easily be transported in the back of any motor car. I did in fact on a number of occasions transfer the equipment to another police building to deal with actual cases of drunkenness and I found that only a few minutes were required to effect the transfer and re-assembly of the apparatus.

2. <u>Choice of Subjects.</u>

It was obvious from the start that, in order to achieve results which would be reasonably applicable to all classes of the male community, relatively large numbers of subjects would have to be examined. Females are rarely charged with drunkenness while in charge of a car, and a supply of female subjects not being readily available their consideration was omitted.

I was very fortunate in having available as subjects the members of the City of Sheffield Police Force, and the Chief Constable readily gave his permission for the utilisation of his men as experimental subjects. All the men examined were therefore fit men whose medical histories were known to me with the exception of three who are not policemen, but are employed on Police Buildings in a civilian capacity. In addition I utilised the figures recorded by ten individuals who had been arrested as unfit to drive through alcoholic intoxication. In all 178 subjects were examined. Some recorded only one reading while others made as many as 21 tests under various conditions. All the men used were therefore known to be healthy or were examined to ensure that they were so. The men varied in age from 17 to 53 years, and, within those age limits, may be considered a fairly representative sample of the male community. I am deeply grateful to those 168 men who attended at the department in their own free time and who loyally co-operated in the work. Without their assistance these experiments could not have been undertaken.

3. Experimental Methods.

I first enrolled twenty men, all under 30 years of age, over 5' 10" in height, and weighing between eleven and twelve stones. Each man, in the first instance, attended at the laboratory daily for ten days. Each day I recorded the number of hours sleep he had had, the time that had elapsed since he got up, and the time since his last meal. I also noted the date, the time of the experiment and the subject's hours of duty for that day.

At his first attendance I carefully explained to each subject what I expected of him. In order to attain uniformity in the instructions given I used to read the following to each subject:- "You must sit comfortably with the bell-push in your hand and with your finger or thumb resting lightly on the button so that you will be ready to press it when required. A light will appear in this aperture (indicating same) a number of times at irregular intervals and as soon as the light shows you must press the button as quickly as possible, hold it down firmly for a "few seconds", and then release it. The object of the test is to see how quickly you can react to the signal. Concentrate all your attention on the light. You will receive warning before the first exposure of the light but thereafter the light will appear at irregular intervals without warning and you must react to it. After you have been tested with the light a number of times the signal will be changed and a bell will ring in place of the light signal. You will be warned when this change in the signals is about to occur and you must react to the bell in the same way as you will to the light".

Following this explanation I then recorded twenty-five readings for each reaction time. Throughout this work each series of readings contained 25 observations to each signal and an average was struck from the total.

The object of this period of 10 days' training was to try to eliminate the effects of practice and to give each subject the opportunity of attaining his established normal reaction time.

On the eleventh day from the start of the experimental period the subject again attended under special conditions.

Instructions were issued to each man on the tenth day that he must have eight hours sleep, at least, that night. On the morning of the eleventh day and not later than 8.0 a.m. each had a standard breakfast of two slices of toasted bread and half a pint of milk. No tea, coffee, alcohol, or tobacco was allowed after 11.0 p.m. on the night before the alcohol experiment, and no food or drink, other than the standard breakfast, was to be taken between that time and 10.30 a.m. next day when the experiment began. The obvious criticism is that bread and milk is one of the best buffers to prevent rapid absorption of alcohol (Mellanby). It was in my opinion necessary to allow these volunteers to have some sort of meal before appearing at the laboratory, because a volume of alcohol, taken on an absolutely empty stomach by a man unaccustomed to its use, would probably have induced nausea and vomiting and thus have ruined the whole experiment. The choice of that particular meal was made because its constituents are readily obtainable by everyone even under wartime conditions; it is quite a small meal and will soon leave the stomach, and furthermore it was felt to be more desirable to allow a specified light meal to which the men would probably adhere than to prohibit food and have some of them taking a meal the constituents of which one did not know. The time interval between breakfast and the ingestion of the alcohol was $2\frac{1}{2}$ to 3 hours and in this time the small meal allowed would have almost all left the stomach. The quantity remaining would be just sufficient to prevent any serious nauseating effects induced by the alcohol and yet would not, I think, act as an efficient buffer to prevent absorption.

On arrival each subject recorded one set of readings to each signal to establish a normal for that day and was then given the alcohol solution which he was required to drink within ten minutes. The first six men were given 100 cc. of whisky at 30 under proof (equivalent to 40 cc. of absolute alcohol) diluted in 200 cc. of water. By the time these men had been dealt with it was found that the dose of alcohol did not produce sufficient effect either clinically, or on the reaction time, and consequently it was decided to increase the dose. The next six subjects were given 100 cc. of whisky neat under the same conditions. This dose of alcohol did produce subjective and objective indications of its consumption but none of the subjects was judged unfit to drive when tested according to the recommendations of the British Medical Association Committee on Tests for Drunkenness. It was, therefore, decided to administer a still larger and more concentrated alcoholic drink and the remaining eight men were given 100 ccs. of whisky with 40 cc. of absolute alcohol added to it. This proved to be a fairly potent beverage and in some cases produced very marked clinical symptoms.

Wheh planning the experimental administration of alcohol the desirability or otherwise of the subject's knowing he was taking alcohol had to be considered. It can be argued that the mere knowledge of alcohol intake might, in an imaginative subject with a knowledge of his own high susceptibility to the drug, lead to subjective and objective manifestations which are not genuine but are partly coloured by his expectation of symptoms of intoxication. In this matter I enlisted the help of a pharmaceutical chemist who prepared a variety of concoctions intended to mask the taste of alcohol. None of these preparations was efficient when mixed with any appreciable quantity of alcohol, and the more efficacious ones were so unpleasant that, even in small doses, they produced nausea when I tested them personally. Dodge and Benedict (1) considered this problem. They concluded that it is practically impossible to mask the alcohol in a solution efficiently. It can nearly always be detected in a solution containing 20% or more. In their opinion to mask it completely it would have to be given in capsules, intravenously, or by stomach tube, and the technique would upset the experimental routine by introducing extraneous disturbing factors. There is also the point that strong flavouring agents would have some pharmacological action. Those workers decided that it may be better from the point of view of the experiments to let the subject know what he

(1) Ref. Dodge and Benedict 12.

is taking than to allow him to guess and perhaps guess wrong. Miles (2) found that it was possible to mask the taste of dilute alcohol (2.75%) but his experience was that when 25 grams of alcohol or more were taken the subjective sensations told the subject that he had had alcohol. Very small concentrations of alcohol can be tasted in unflavoured drinks and Miles quotes Hallenberg to the effect that this is possible even at concentrations as low as 0.01%.

In the light of this work, and of my unsuccessful attempts to obtain an efficient masking medium devoid of effects of its own, I decided not to attempt to hide from the subjects the fact that their test beverage contained alcohol. In any case my intention was to try to produce clinical drunkenness in my subjects, and their subjective sensations would soon have notified them as to the active constituent of the solution consumed.

In the case of the first 20 subjects a set of readings was taken at intervals of half an hour up to 2½ hours after taking the alcohol; i.e., five alcohol readings in all. Prior to each recording under alcohol the man was tested clinically for fitness to drive according to the recommended routine, and an opinion formed on this point before testing his reaction times to light and sound. At the completion of the experiment an average was taken of each set of readings and this figure entered as the reaction

(2) Ref. Miles 33.

time to the appropriate signal at the time in question.

Having dealt with the first twenty subjects by the method described above it was quite obvious, from an examination of the result of practice, that it was not possible for an individual to attain an established normal reaction time, due to minor daily variations in his metabolic state. Mere inspection of the figures shows that there is a small upward and downward swing varying in degree and not at all consistent for each individual. The effects of practice on a very much larger number of subjects will be considered statistically later in the thesis when it will be found that the conclusion reached by mere inspection of the figures - admittedly a very rough and unscientific method - is borne out by statistical analysis.

A further point considered at this stage was that while an established normal reaction time could not be reached practice might have some influence on the results and therefore experiments of this type would yield results which, while academically interesting, could hardly with fairness be applied as a criterion of unfitness to drive to the subject of an actual charge. The accused has no opportunity to practice with the machine, his first reading being taken on the occasion of the clinical examination in relation to his alleged offence. I therefore decided at this point to alter my technique to one involving conditions more nearly analogous to those met with in real life.

The remaining 41 subjects were given no preliminary practice and were not selected as regards age, weight, or height, but were chosen more or less at random.

Each man attended for the experiment under the same conditions as to diet and sleep as these previously dealt with. On arrival and after making the usual entries, the subject was given alcohol which he had to consume within ten minutes. One hour after complete ingestion of the fluid I tested the subject clinically as to fitness to drive, and then recorded a set of readings, after giving the same instructions to the subject as I had done to the previous group of men on their first attendance. Two other clinical tests and sets of readings were then made at 1½ and 2 hours respectively from the time the alcohol had been taken. In an actual case, of course, only one set of readings would be recorded but, in order to utilise the alcohol as far as possible, and to be certain that the time of highest blood alcohol and greatest clinical effect would be included in each series, I decided on three sets of readings. It is generally agreed that alcohol, taken on a relatively empty stomach, exercises its maximum effect at from one to two hours following ingestion. Next day I recorded one set of readings to establish a normal for that subject. Of the 41 subjects in the second series 13 were given 100 cc. of whisky and 40 cc. of absolute alcohol, 19 had 50 cc. of absolute alcohol added to the same volume of whisky, one was allowed 60 cc., and the remaining eight took 75 cc. in 100 cc. of whisky.

In order to obtain some knowledge of the alcoholic history of the subjects I asked each man to fill in the following questionnaire and in order to encourage truthfulness I promised that it would be treated as a confidential document.

<u>Strictly Confidential.</u>

NAME.	ADDRESS.	DATE.

POLICE NUMBER.	EXPERIMENTAL NUMBER.

	Regular Daily Alcohol Consumption.	Effects.
Father		
Mother		
Brothers 1		
2		
3		
Sisters 1		
2		
3		

Is there any habitual use of other drugs by any members of the family?

Is there any nervous or mental disease in the family history?

Is there any excessive use of alcohol in the family history?

<u>Subject's Personal History</u>. <u>Age</u>. <u>Height</u>. <u>Weight</u>.

Are you a total abstainer? If not state:-

1. Total daily consumption of alcohol and kind usually taken?
2. When did you last have alcohol and how much was taken?
3. Largest amount ever taken?
4. Have you ever been intoxicated?

   How much alcohol did you have and when did this happen?

   What kind of alcohol was it?
5. How much alcohol can you take without noticeable effects?
6. What are the first effects you observe after taking alcohol?

   Excitement or the contrary.

   Talkative or the contrary.

   Happy or sad.

   Peculiar sensations.

   Effects on emotions: temper.

Effect on routine work: strength, accuracy, etc.

Effect on sense of propriety: morals.

Effect on digestion: urine.

7. How much tea or coffee do you take daily?

To begin with I had some difficulty in deciding how much alcohol to give to produce the desired clinical effects and in the first series I erred on the side of caution. Later in the light of the knowledge of the subject's alcoholic habits as revealed in the questionnaire and of the experience I had gained in earlier experiments, I was able to decide more accurately. Obviously I was anxious to give enough alcohol to produce clinical intoxication but I did not want my subjects to become comatose and unable to record results at the times required. At no time, however, could I estimate the correct dose to produce unfitness to drive even with a knowledge of the alcoholic habits of the subject, because of the different conditions under which the alcohol was taken normally and experimentally and of differences in concentration, and on account of the factor of inherent tolerance. All this accounts for the variety of doses administered. In any case the clinical condition and the reaction times are the factors under consideration while the actual dose taken does not matter practically. It is the question of fitness to drive that has to be considered not the number of drinks consumed, and that factor should have no bearing on an actual case.

The examination of persons arrested for being unfit to drive a car because of alcoholic intoxication is not conducted in my department, and in these cases I had to transport the equipment to another police building where it was re-assembled. There the usual clinical examination was carried out followed by one set of readings of reaction times to light and sound. These accused persons are normally released on bail a few hours after arrest and they were asked to attend at the laboratory next morning in order that I might take their normal reading after the effects of the alcohol had passed off. It was particularly impressed on these men that it was in their own best interests to treat the test seriously and to concentrate on it to the best of their ability, and I took great pains to ensure that they understood the instructions thoroughly.

At a certain stage in the experiments I thought it desirable to enquire into the effects of fatigue. I examined sixteen men from this point of view particularly, but I was able also to utilise the normal readings I had taken from the sixty-one subjects who had been given alcohol, as records had been kept of their duties and the lapse of time since they had started the day. These sixteen men were asked to attend for test morning and evening for four or five days in succession. Most men attended from Monday till Friday in one week but in some cases, for various reasons, only four attendances were possible. This provided me with a series of observations taken before and after a day's work, after a certain known amount of sleep, and a certain definite number of hours since rising.

On commencing to consider my figures statistically I noticed that my observations concerned men varying in age from 17 to 36 years. When I appreciated that, from the point of view of making allowance for the age factor, their series was too limited, and that I should have to extend the readings to a series of men over the age of 36, I recruited 82 subjects varying in age from 36 to 53 years. These volunteers were only asked to attend on one occasion. With these figures I was able to include 18 readings from men of this age group. These readings had been omitted previously in order to avoid having a straggling tail to the curve of age distribution. This made a total of 102 observations on this particular point.

It is hardly necessary to point out that during the actual recording of reaction times precautions were taken to ensure that no extrinsic noises within the premises would distract the subject's attention. If any sudden noise did inadvertently occur then the reading taken at that time was omitted from the series. Great care was exercised to transmit the signals at irregular intervals so that there was no possibility of anticipation, at the same time avoiding too long an interval between signals during which the subject's attention might tend to wander.

4. Clinical Effects and Subjective Sensations Produced by Alcohol.

As stated above the first six subjects took 100 cc. of whisky diluted to 300 cc. with water, and the second six had 100 cc. of whisky neat. Not one of these twelve subjects was judged clinically unfit to drive by the standard tests. Two had no objective signs or subjective sensations due to the alcohol. Nine of the remaining ten subjects were clinically sober throughout and showed no external manifestations of having had alcohol, though seven of them felt giddy at some stage during the experimental period. Only one man showed defects in co-ordination and these were mild in degree.

The remaining 49 experimental subjects all had doses of alcohol of 100 cc. of whisky with 40 cc. of absolute alcohol or more added. Eighteen of these were unfit to drive at some time during the test period, and eleven had serious disturbances of co-ordination. Twelve men were at all times clinically sober, and nineteen, while still judged fit to drive by clinical standards, yet showed some inco-ordination or other mild signs of alcoholic intoxication.

Of the twelve who were clinically sober three experienced no subjective sensations of any kind. One of these had a considerable acquired tolerance to alcohol but the other two were only accustomed to occasional small doses of the drug. The most common subjective sensation was one of tiredness and a desire to sleep. One man felt an intense desire to sleep but was unable to do so, while eleven subjects did actually fall soundy asleep. Dizziness was experienced by twenty-two men and many more felt "muzzy" though not actually giddy, while fifteen men complained of faulty memory and inability to concentrate. Nine confessed to visual disturbances, often of diplopia, and seven men at an early stage of the experiment experienced a feeling of well-being, happiness and contentment. In four of the subjects definite evidence of loss of emotional control was noted. One man alternatively wept and had outbreaks of hysterical laughter, while two others felt inclined to laugh for no apparent cause but could exercise sufficient control to check the impulse.

It was found that by the end of the experimental session all the men examined were either completely recovered from the effects of the alcohol or were sobering rapidly.

One observation I made was that the effects of alcoholic intoxication may pass off with striking rapidity. Even in half an hour a man may pass from the stage of being hopelessly "drunk" to comparative sobriety. For example, in the case of subject 683, ninety minutes after taking the alcohol he was asleep and on being awakened was incapable of passing any of the standard tests for co-ordination. Half an hour later his co-ordination had improved sufficiently for his being graded as a borderline case. A similar improvement was manifested in his reaction times the reading for light improving from 60.2 at 90 minutes to 40.7 hundredths of a second at 2 hours. This observation under experimental conditions is borne out by practical experience. It often happens that the police officer's description of the accused's condition at the time of arrest does not in any way correspond to that discovered at the medical examination some short time later, and this may lead the bench, the defending solicitor and the public, to the conclusion that the officer is loading the evidence against the accused in order to secure a conviction. In the light of this experimental experience, which was not confined to one subject but was many times observed, it is to my mind clear that such a discrepancy is not beyond the bounds of possibility. If this can happen experimentally where the subject is at his ease, how much more readily could it happen when a man is suddenly pounced upon by a policeman and placed under arrest? The mere shock of this, or of being involved in an accident, is often sufficient to produce or accentuate this sobering process. A further corollary to this is that it is extremely unwise for a medical witness to express an opinion as to the state of the accused at any time other than that of the actual examination.

One point worth underlining is that only infrequently under experimental conditions, does one observe the traditional psychological changes associated in the popular mind with alcoholic intoxication. Eight of the sixty-one subjects experienced a transient feeling of well-being or contentment, and this was, in all cases where the larger doses were administered, followed by symptoms of narcosis to a greater or lesser degree. It is striking that 33 of the 49 subjects subjected to the more potent doses complained of sleepiness and that 37 of them showed some definite signs of impaired neuro-muscular control, apart from visual disturbances.

5. Physiological Aspects of the Results.

In all 509 recordings of reaction times to light and sound under normal conditions were made, the mean age of the subjects being 30.46 years, and the ages ranging from 17 to 53 years (Table iv). One hundred and sixty-nine subjects were utilised for this particular section of the work. The mean reaction times to light and sound were found to be 28.86 and 19.19 hundredths of a second respectively (Tables i and xv). This total number of observations was obtained from men of two age groups. The main contribution was made by a series of 407 observations on 83 subjects with a mean age of 27.28 years and varying in age from 17 to 37 years (Tables iv and xv). The mean values of the reaction times to light and sound in this group were 28.64 and 18.80. One hundred and two readings from men of a mean age of 43.16, with an age range of from 37 to 53 years, form the second group, and in this case the readings for light and sound were 29.72 and 20.69 respectively (Table xvi A). It will be noted (Table i) that the mean reaction times to light in the various groups of readings correspond fairly closely to one another and to the mean value of the total of 509 observations. In the case of sound the correspondence is not so close, the older group of men showing a somewhat higher average than the younger group. This finding at once suggests that in the case of the reaction time to light there is little relationship between age and reaction time, while in the case of sound there is a closer positive relationship. This is borne out by the correlation coefficients which for reaction time to light and sound with age are +0.27 and +0.62 respectively in the case of the 37 to 53 years age group (Table i). This matter will be dealt with in detail below.

Table iv shows the range of the normal readings. It appears for this that there is considerable variability in both reaction times, the readings being scattered over a wide range. This, in fact, is what one would expect in view of the known variability of any biological function. However it can be seen from the histograms (Graphs 1 and 2) that in the case of both series of normal readings, there is what approximates to a "normal" distribution, the values being almost evenly distributed on either side of the mean.

The figures, of which these histograms are graphic representations, show that in the case of the reaction time to light only 3.19% of the readings lie above the 35.0 to 36.5 group, while in the case of sound only 2.96% lie above the 23.7 to 24.9 group. This indicates that abnormally high or low reaction times are relatively rare but are encountered.

Obviously with any variable quantity there will be a certain spread on either side of the mean. This spread can be represented by the range, as seen above, but this does not give a true picture of the state of affairs, because a single abnormally high or low reading may markedly increase the range and the whole apparent variability is therefore falsified. The true index of variability about the mean is the standard deviation (σ). This quantity is the mathematical expression of the average "swing" or average variability of the quantity under consideration, and is arrived at by taking the square root of the difference between the mean of the squares of the readings and the square of the mean of the observations (1). It will be seen (Table i) that the average variability, as shown by the standard deviation, is relatively small in both cases. The standard deviation of the reaction time to light is 4.25 for the whole series, 5.22 for the older men and 3.94 for the age group up to 37 years. This in effect means that there is an average swing of 4.25 hundredths of a second on either side of the mean and it is a more reliable

(1) Ref. Bradford Hill 22.

measure of variability than the range of the readings. In the case of the reaction time to an auditory stimulus the value of σ for the series is 3.63. These figures translated into percentages give a more accurate picture of relative variability where the means are not of the same order. This is done by calculating the coefficient of variation which is arrived at by the formula:-

$$\text{Coefficient of Variation} = \frac{\text{Standard Deviation}}{\text{Mean}} \times 100$$

In my series of normal readings for light and sound these coefficients are 14.7 and 18.8 respectively, which indicates that relatively the reaction time to sound is rather more variable than the reaction time to light (Table v).

The mean values quoted for the reaction times to light and sound are the averages obtained from the sample of the universe examined. The value need not necessarily be the same for all samples of the universe - the means will vary somewhat. It can be shown that the true mean of the universe sampled will lie somewhere within the limits of estimated mean $\pm 2 \times \frac{\sigma}{\sqrt{n}}$ where σ is the standard deviation and "n" the number of observations in the sample. This is based on the assumption that the true value of σ for the universe will be very close to that actually obtained. The factor derived from the expression $\frac{\sigma}{\sqrt{n}}$ is known as the standard error of the mean and readings removed from the mean by more than twice the standard error are very rare.

Using this method (Table vi) we find that the **true mean** of the universe sampled will lie between 28.48 and 29.24 in the case of reaction time to light, and between 18.87 and 19.51 in the case of reaction time to sound.

In the same way the standard deviation will vary from sample to sample, and the standard error of this quantity $\left(\frac{\sigma}{\sqrt{2n}}\right)$ will show how much variability this quantity is in fact likely to exhibit from one sample to another in the same universe. From this quantity the true value of the standard deviation of the universe sampled can be calculated, or to be more precise the limits within which it will lie. These values are shown in Table vi.

If the reaction time is to be used as an index of intoxication than any variable factors liable to influence the result must be considered statistically in relation to the reaction time. In other words the degree of relationship between the variable and the quantity under consideration must be estimated, and allowance made for it if necessary. This is achieved by calculating the correlation coefficient, which may vary between +1 and -1. If the sign is positive it means that the association is direct; i.e., one quantity increases with the other, while if negative the relationship is inverse, and as one value rises the other falls. If the coefficient is unity then the simple proportional dependence of one variable on the other is complete.

The value of the coefficient of correlation between two quantities may be arrived at by means of the following formula:-

$$\sigma_{s+l} = \sigma^2_s + \sigma^2_l + 2\, r\, \sigma_{sl}\sigma_{sl}$$

where σ = standard deviation

s and l = variables in question

and r = coefficient of correlation

The values of σ for each quantity and the sum of the quantities is arrived at by the method already indicated. Alternatively the value of σ may be calculated by grouping as shown in Table xxv. The shorter method, it can be seen, gives a result which in most cases approximates fairly closely to that achieved by the more accurate, but rather laborious extended method. As with the mean value and the standard deviation of the quantities, the coefficient of correlation between two variables will be subject to a standard error, because its calculated value is based only on a sample of the universe under consideration. The standard error of the correlation coefficient is obtained from the formula $\frac{1}{\sqrt{n-1}}$. Its value therefore depends on the number of observations. There are, as far as I have been able to discover, no definite limits laid down for varying degrees of correlation but according to Bradford Hill the same rule applies to this quantity as to others, namely, that a value greater than twice the standard error is unlikely to have arisen by chance and can be regarded as significant.

The correlation coefficient between reaction times to light and sound is +0.428 (Table i). This figure represents a relatively low degree of correlation but one which is significant as the standard error is 0.0496 (Table ix). This means that there is some degree of relationship between these two reaction times but that it is not close, though direct. In other words reaction times to sound and light are only partially dependent the one on the other, and one reading does not directly reflect changes in the other. I conclude therefore that both should be considered in assessing the degree of intoxication.

The correlation between age and reaction times must next be considered. Reference to Table i will show that between the ages of 17 and 37 years there is a coefficient of +0.142 between age and reaction time to sound, which, while just significant in terms of the standard error, is very low and of no practical importance. However, in the older age group the picture changes because here the correlation between these two variables is represented by a coefficient of +0.62, which is 5.7 times the standard error (Table ix). This represents a fair degree of correlation, and these figures indicate that over the age of 37 years an increase in age is accompanied by some increase in reaction time to sound.

The correlation between age and reaction time to light is represented by a coefficient of +0.25, taking both age groups together (Table i). This figure is just significant, and in the older age group alone the coefficient is of the same order. This is a very low degree of correlation and is of no practical importance from the point of view of this thesis.

Tables have been constructed (2) giving the value of the coefficient of correlation necessary before significance can be concluded where small numbers of observations are concerned. In the older series there were 84 observations from the same number of individuals - the eighteen readings from two men being omitted for the sake of uniformity. The coefficient of correlation between sound and age in this group is +0.62. According to Fisher's table, for 80 readings and with a level of significance of 1:100, r must exceed 0.2830. Therefore a coefficient of correlation of +0.62 is significant. The coefficient of correlation between light and age in the same group is +0.27. From the table the levels of significance are 0.1829, 0.2172, 0.2565, and 0.2830 for probabilities of 1:10, 1:20, 1:50 and 1:100 respectively. This particular value of r is well above the 1:50 level and may be considered just significant.

From the practical point of view the influence of

(2) Ref. Fisher 16.

fatigue on reaction times must be considered, as pointed out above. If fatigue increases the reaction time, then allowance must be made for this in assessing the significance of any reading taken in an actual case of drunken driving. One can quite well imagine a defending solicitor using this factor as an excuse for his client's having an abnormally slow response to the signals. The argument would be that the test was made when the accused was tired, and that this accounted for the departure from the "normal". Each individual spends the day in his own way and some persons tire more quickly than others. I found it difficult to assess fatigue and to measure it by any method that could be expressed numerically so I decided that, on the assumption that a man is at his best after a period of sleep, a fair and generally acceptable measure of fatigue would be the number of hours since rising to start the day.

Using a series of 423 observations taken from 83 individuals (Table xvii), and covering up to $21\frac{1}{2}$ hours since rising, I found that the coefficient of correlation between the variable and reaction times to sound and light were respectively -0.02 and -0.073 (Table i). This signifies that fatigue, as estimated by the method stated, has no relationship to visual and auditory reaction times. One could quite well imagine that, in states of utter exhaustion, there might be a significant correlation between fatigue and reaction times, but I think one can fairly conclude that in ordinary circumstances there is no practical relationship.

The condition of the alimentary canal is known to influence many physiological functions, and a full stomach has a well known reputation, based on sound physiological principles, for producing a damping of mental and bodily activity. This variable was studied in a series of 242 observations (Table xviii). The condition of the alimentary canal at the time of the test was assessed in terms of the lapse of time since the last meal. The coefficient of correlation between the reaction time to sound and the number of hours since the last meal is -0.58 (Table i), which is an inverse relationship and means that the nearer to a meal, and therefore the greater the alimentary activity, the slower the reaction time. This figure indicates moderate correlation and is definitely significant. Account therefore may have to be taken of it in assessing abnormal alcoholic readings. Strangely enough the correlation with reaction time to light is -0.08 (Table i) which is not significant and can be ignored. It appears therefore that a full stomach, to some extent at least, slows the reaction time to sound but has no effect on reaction time to light.

As stated above, it was obvious from inspection of the figures recorded by my first twenty subjects that practice did not enable a man to attain an established normal reaction time. If the reverse had been true, as postulated by Jonnard and Maire (3) and by Cheney (4), then one would have expected a high degree of correlation between reaction times and practice, as assessed by the numerical order of the reading. Based on 383 readings (Table xix) I found that the coefficient of correlation between reaction time to light and the numerical order of the reading is -0.21 (Table i). This figure is approximately four times the standard error (Table ix) and is therefore significant, though it represents a low degree of correlation. The coefficient of correlation between practice and reaction time to an auditory stimulus worked out at -0.033, which is not significant (Table i).

The discrepancy between these two coefficients may be explained by two theories. The visual paths in the brain are more complex and involve a larger number of synapses than the auditory paths, and this may account for the fact that there is a slight correlation between reaction time to light and practice in operating the machine. An alternative explanation is that, as the reaction time to light was always tested first, this may have served as practice on the first occasion the machine was used, thus eliminating this factor from the reading to an auditory stimulus which followed it. Personally I favour the first hypothesis. The second theory could be subjected to proof by repeating the observations on a fresh series of subjects but taking the sound reading first. This point being of

(3) Ref. Jonnard and Maire 26. (4) Ref. Cheney 8.

academic interest only was not pursued further. Practically it can be concluded that practice on this particular machine has no appreciable effect on the reaction time and one can afford to ignore it.

The problem of assessing whether any of these physiological factors, showing a moderate correlation with reaction times, require to be considered in the practical application of reaction times as a test for unfitness to drive a car because of alcoholic intoxication will be dealt with later in this thesis, when discussing the medico-legal implications.

If two variables are related and their interdependence can be represented most adequately by a straight line graph, then we can calculate the equation for this line - the regression line. This equation enables us to calculate the change in one variable for unit change in the other, and the factor involved is known as the coefficient of regression. The regression equation for two variables "l" and "t" is:-

$$l - \bar{l} = r_{lt} \times \frac{\sigma_l}{\sigma_t} (t - \bar{t}) \ldots\ldots\ldots\ldots (5)$$

The regression equations and coefficients relating the variables, discussed above, with reaction times to light and sound are shown in Table viii. From these equations one can predict one variable given the value of the other. If the coefficient of correlation between the two variables is unity then this calculation will supply an accurate

(5) Ref. Bradford Hill 22.

answer, but, unless the correlation is absolute the value obtained will only be a theoretical figure though it expresses the order of the variable required.

6. The Effect of Alcohol on Reaction Times.

In all 215 observations were made on the effect of alcohol on reaction time, irrespective of whether the dose of alcohol produced clinical unfitness to drive or not (Table xx). The mean values of all the alcohol readings were 37.50 for light and 26.30 for sound respectively as against 28.86 and 19.19, the normal averages. It is clear therefore that alcohol increases the reaction time, and this confirms the results of most of the publications reviewed above.

When 100 cc. of whisky was diluted in 200 cc. of water the results were inconclusive. Of the six subjects who were given this dose four showed a decrease in the reaction time to light, and two an increase half an hour after taking the alcohol. All those who showed an initial fall in reaction time maintained this throughout the experiment. Only one of the subjects showed a persistent increase in reaction time to light and this disappeared 2½ hours after the alcohol was taken. This dose of alcohol had a tendency to increase the reaction time to sound, five out of six subjects showing some deterioration.

When 100 cc. of whisky were given neat the clinical and subjective effects were more marked. Four of the six subjects showed a definite increase in their reaction times to light the remaining two recording a decrease. As these two subjects showed no evidence clinically of alcoholic intoxication, and only experienced very mild subjective sensations in comparison with the others, one can deduce that the alcohol had little or no effect on them. Of the four subjects showing a persistent increase in reaction time to light three of them had their maximum reading one hour after the dose and the fourth $1\frac{1}{2}$ hours afterwards. The increase varied from 6 to 30% in those four cases. In the same six subjects the reaction to an auditory stimulus showed the same tendency to increase in five cases.

A dose of 100 cc. of whisky with 40 cc. of absolute alcohol added produced an increase in reaction time to light in seven out of eight subjects, the man showing no effect on his reaction time being clinically sober throughout the experiment. In his case the absence of effect on the clinical condition runs parallel with the absence of effect on the reaction time. These eight subjects all had their reaction times to sound increased by this dose of alcohol.

At first, while the dilute beverage was being used, it appeared superficially that the alcohol might be responsible for a decrease in the reaction time. To test this eighteen subjects reported at the laboratory on the day following the alcohol experiment and were given a draught of water equal in volume to the alcohol taken the day before, after one reading had been taken to establish a normal for that day. Reaction times to sound and light were then recorded at intervals of half an hour. It was found that half an hour after taking the water six men showed an increase in reaction time to light while twelve exhibited a decrease. At one hour the proportions were the same. Half the men showed an increase and half a decrease in reaction time to sound after half an hour, and the proportions were the same after the lapse of a further 30 minutes. It is interesting to compare this result with that obtained using the dilute alcohol solution. In both cases twice as many subjects showed a decrease in reaction time to light as showed an increase. It is clear, therefore, that in the case of the first series of subjects the apparent decrease in reaction time to light due to alcohol is a fallacy, being equally produced by water. This might be attributed to the fluid bulk alone. On comparing the effect of dilute alcohol and water on reaction time to sound we find that while water produced no definite tendency the dilute alcohol increased the reaction time. It appears that the reaction time to sound is more susceptible to the effects of alcohol than the reaction time to light.

While admittedly only a small number of subjects was investigated in making this comparison between the effects of dilute alcoholic solutions and water on reaction times the result obtained may serve as a possible explanation of the contradictory results reported by some of the earlier workers (1).

If one studies the results of the subjects who had ten days practice before the alcohol experiment one finds that eleven of the twenty men show an increase in their reaction time to light. The distribution of the maximum readings was as follows:-

$\frac{1}{2}$ hr.	-	1 subject
1 hr.	-	5 subjects
$1\frac{1}{2}$ hrs.	-	3 subjects
2 hrs.	-	1 subject
$2\frac{1}{2}$ hrs.	-	1 subject

From this it is obvious that the effect of the alcohol is most pronounced at one to one and a half hours after consumption, and a higher proportion showed their maximum reading at one hour than at any other time. In the light of this it is not surprising to find that, in the case of the men who were allowed no practice, the highest reading was often the first one recorded, i.e., one hour after ingestion. This fact is important because a high first reading might be attributed by some to lack of practice or the novelty of the procedure. This factor can be eliminated by the low correlation coefficient between reaction time and practice, and by the above observation in men who had had ample practice. The max-

(1) Ref. Kraepelin 28 and Warren 50.

imum effect on the reaction time to sound also occurred one to one and a half hours after taking the drink.

It can therefore I think be fairly concluded as a result of the above analysis of the result that alcohol at no stage decreases the reaction time but tends to increase it, and the maximum effect occurs about one to one and a half hours after ingestion.

This total of 215 readings taken from subjects under the influence of alcohol is made up of two groups - 167 observations on those fit to drive clinically, and 48 on men who were judged clinically to be incapable of having proper control of a car.

In the first group the mean reaction times to light and sound are 32.15 and 21.31 respectively (Tables ii and xxi), and these figures compare quite favourably with the normal averages (Table i). For those who were unfit to drive there is a marked average increase to 56.1 for the light reaction and to 43.50 for the sound reaction (Tables ii and xxii). Included in this series there are three readings from one man which are extreme, so much so that, as will be explained below, they could be considered abnormal (Table x). With these readings omitted the clinically unfit average becomes 44.77 for light, and 32.32 for sound (Table ii). A comparison of Tables i and ii also shows that the effect of alcohol is to increase the standard deviation of the reaction times considerably, indicating an increased variability in the readings due presumably to impaired powers of continuous concentration.

As would be expected alcohol increased the range of the readings, but some of those from people clinically unfit to drive fall within the range of the normals. It was to be expected that there would be an overlap of this kind, and its extent is shown pictorially in Graphs 1 and 2. It will also be seen from the histograms that the distribution of the reaction times of the clinically unfit does not conform with that of the "normal" curve. This discrepancy may possibly be explained by the relatively small number of readings from individuals unfit to drive.

To calculate the relative increase due to alcohol based on the individual's own normal readings tables were constructed (Tables xxiii and xxiv) showing the average normal (E) and the average alcoholic (D) readings for each man for light and for sound. By deducting the E reading from the corresponding D reading the relative increase due to alcohol for each individual was obtained. These readings were classified according to the subject's fitness or unfitness to drive. The average results are shown in Table iii. Two figures are quoted for the clinically unfit. The first, showing a relative increase of 23.37 and 20.98 hundredths of a second respectively to light and sound, includes all the observations. However, in the case of one subject (No. 539) the increase was exceptionally large, amounting to 195.9 in the case of the visual reaction and 192.1 for sound. These readings are 28.07 and 23.70 times the standard deviation removed from the mean respectively, are therefore exceptional, and should be omitted to give a clearer average picture. With these extreme readings omitted it will be seen (Tables iii and xxiv) that alcohol, in amount sufficient to produce clinical unfitness to drive, leads to an average relative increase in reaction times to light and sound of 14.28 and 11.94 hundredths of a second respectively. The relative increase in these subjects fit to drive was only 4.53 for light and 3.20 for sound. Unfitness to drive was, as would be expected, accompanied by a corresponding increase in standard deviation and in the range (Table iv).

By calculation of the standard error of the mean we find (Table vi) that the true mean for the clinically fit lies between 31.15 and 33.15 in the case of light and between 20.75 and 21.87 for sound. The true means for the unfit subjects lie within much higher limits, namely, 42.29 and 47.19 for light and 28.24 and 36.44 for sound.

State.	Mean Reaction Time to Light.	Mean Reaction Time to Sound.
Normal	28.86	19.19
Clinically fit to drive	32.15	21.31
Clinically unfit to drive	44.77	32.34

From the above table we find that the differences between the clinically unfit and the normal average readings are light 15.91, and sound 13.15, and that the differences between the unfit and the fit (alcoholic) means are, light 12.62, and sound 11.03.

We have now to consider whether these differences are significant or might have arisen by chance. The standard error of the difference between two means is derived from the expression $\sqrt{\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}}$ where n_1 and n_2 are the numbers of observations in the respective series and σ_1 and σ_2 their standard deviations (2). The standard errors of the differences between the normal mean and the average of the clinically unfit readings is 1.257 for light and 2.057 for sound (Table vii). The actual differences are therefore 12.7 and 6.4 times these standard errors of the differences and, as ordinarily any value over twice the standard error is regarded as significant, it is very unlikely that these results have occurred by chance. The standard error of the differences between the clinically fit and clinically unfit means for light and sound are 1.34 and 2.07 (Table vii) and the actual differences are respectively 9.4 and 5.3 times these standard errors. These differences then are also unlikely to have been the result of chance in the samples examined.

As has already been pointed out the coefficient of

(2) Ref. Bradford Hill 22.

correlation between reaction times for light and sound in normal male adults is +0.428 (Table i). We find, however, that under the influence of alcohol the correlation between these two quantities becomes very high, namely +0.947 (Table ii). This means that in normal people the reaction times for light and sound are partially independent, while, on the other hand, they are so highly correlated in those who were known to have taken appreciable quantities of alcohol that their relation is completely represented by a straight line graph. The considerable independence of the two reaction times in normal people requires that both should be taken in all suspected cases. The value of one could, if desired, be computed from the value of the other using the straight line graph mentioned above. If the two actual values are above the normal (taking account of normal variation) and if the computed value of the second reaction time agrees with the actual value (again taking account of normal variation), then the individual could be taken to be under the influence of alcohol or otherwise abnormal in these sensory mechanisms. When however, we consider those unfit to drive, the degree of correlation between the reaction times to visual and auditory stimuli falls to +0.855, and to +0.54, when the extreme readings are omitted. For this small group of 45 observations the level of significance given in Fisher's table is 0.3932 and therefore a coefficient of correlation of +0.54 can be considered definitely significant.

It is clear,therefore, that the theoretical method outlined above would merely indicate alcoholic intake and nothing more, and as this can be detected quite simply by clinical means the method is not a practical one. Furthermore, in view of the lessened correlation between the two reaction times in those clinically unfit to drive, it could not be put into practical application as far as the estimation of the degree of drunkenness is concerned. One can however conclude, that in all stages of alcoholic intoxication the correlation between reaction times to light and sound is greater than in normal individuals.

It is quite obvious from consideration of the standard errors of these coefficients of correlation that they are significant (Table ix).

Regression lines illustrating the relationship between reaction times to light and sound under normal conditions, and after taking alcohol, are shown in Graphs 6, 7, and 8. The regression line relating light (l) to sound (s) is drawn by taking "l" as abscissae and "s" as ordinates. Then draw the ordinate corresponding to mean "l" and the horizontal at the level of mean "s". The meeting place of these lines is one point on the regression line and only one other point is necessary to draw the line. The fundamental equation of the regression line is:-

$$\frac{Y - \bar{Y}}{\sigma_y} = r \times \frac{x - \bar{x}}{\sigma_x}\,.$$

clearly, at a distance O_x from the mean of x

$$\frac{Y - \bar{Y}}{\sigma_y} = r$$

$$\therefore Y - \bar{Y} = \sigma_y r$$

$$\therefore Y = r\sigma_y + \bar{Y}$$

This gives the second point on the ordinates corresponding to the point $x + \sigma_x$ on the abscissae.

There are two regression lines but only one is drawn in each case.

A consideration of the three graphs shows that under alcohol the slope of the regression line increases. The slope of the line is derived from the expression $r_{sl} \times \frac{\sigma_s}{\sigma_l}$, and by means of this formula it is possible to assess the factor responsible for the change in direction of the line.

The slope of the normal regression line relating reaction times to light and sound is

$$.428 \times \frac{2.94}{3.94} = .428 \times .74$$

The slope for the same relationship in persons clinically unfit to drive is

$$.54 \times \frac{13.74}{8.34} = .54 \times 1.65$$

The slope of the line for all the alcohol readings (i.e., both clinically fit or unfit to drive) is

$$.947 \times \frac{23.65}{24.16} = .947 \times .98$$

When all the alcohol readings are included the increase in the slope, which is of the same nature as the increased slope in the line relating reaction times to sound and light in the clinically unfit, is principally due to the higher correlation between sound and light in this state. The regression line for those subjects clinically unfit to drive shows an increase in slope due mainly to the increased variability of the reaction time to sound.

7. Medico-legal Aspects of the Results.

Before embarking on this section it would be well to summarise the physiological results detailed above. There seems to be no doubt that alcohol substantially increases the reaction times to light and sound, and the effect on the reaction time may sometimes be noticeable even in the absence of any clinical manifestations. The range of the readings is also increased, and the substantial differences between the normal and the alcoholic means are not due to chance. Alcohol also produces an increased variability in the readings, due to decreased power of continuous application. Under the influence of alcohol the correlation between reaction times to light and sound is increased.

Previous workers (1) have proved a decrease in driving skill due to alcohol and as speed of reaction may, in an emergency on the road, be vitally important, and it is reduced by alcohol, it seems reasonable to utilise the changes in reaction time due to alcohol summarised above as a basis for measuring fitness or otherwise to be in charge of a car after alcoholic indulgence. Utilising reaction times as an index does not involve the measurement of some function which is affected by alcohol but does not necessarily have a practical bearing on the individual's ability to drive. The increase in reaction time may be the factor to which an accident is clearly attributable, and it has been demonstrated that this increase is substantial in alcoholic intoxication.

Obviously in experimental work of this kind one has to set some sort of standard against which the reaction times are to be compared. If the method is to be used practically then obviously the standard of comparison should be the recommended tests at present in use. I therefore examined my subjects according to the approved routine and assessed their fitness to drive by this standard. It will of course be obvious that the clinical tests were subject, as they always must be, to individual interpretation, and therefore, the levels I shall attempt to establish may not, for this reason, and for others that will be

(1) Ref. Vernon and others.

discussed below, be generally acceptable. In any case all I hope to achieve is to demonstrate that in this we have a potentially practical method of assessing fitness to drive in alcoholics. It may ultimately be possible for some high authority later to establish that irrespective of clinical condition an increase in reaction time above a certain level is a legal bar to the efficient handling of a motor car.

It is clear from a consideration of the histograms (Graphs 1 and 2), the range of the readings (Table iv), and the "normal probability curves" of normal and clinically unfit readings for light (Graph 3) that there is a considerable overlap of the readings taken from normal and clinically unfit men. This is as one would expect. It is obvious, therefore, that one cannot in fairness conclude that, if a reading is over the mean of those clinically fit to drive, then the individual is unfit to drive. While the average readings may be generally applicable to any large body of men, in view of the normal variability of such measurements, they cannot be applied rigidly to any one individual.

If any series of observations is "normally" distributed then, by virtue of the nature of the "normal curve", practically 100% of these observations will fall within the limits of three times the standard deviation on either side of the mean. If we consider first the alcohol readings for those clinically fit to drive then the upper limits of clinical fitness (i.e., mean + 3σ) for light and sound will be 51.59 and 32.14 respectively. (Table xi). In the same way the lower limit of clinical unfitness (if the readings are normally distributed) would be 19.75 for light and zero for sound (Table x). Using 3σ as the standard, for the reason given above, the extent of the overlap (i.e., lower limit of clinical unfitness to upper limit of clinical fitness) extends from 19.75 to 51.59 for the reaction time to light, and from zero to 32.14 in the case of sound. If these upper limits were set as the critical level then many actually clinically unfit would escape because of the extreme width of the overlap area.

On studying Table xi it will be seen that the lowest reaction time to light recorded by anyone judged clinically unfit to drive is 35.3, andnone of the individuals in the clinically unfit series recorded a normal reading above this level. The lowest reading to sound from anyone who was unfit to drive was 20.6, but five men recorded normal readings over this level. Therefore none of the subjects showed an overlap in both cases either actually or mathematically (Table xi). Because the actual number and the calculated number of overlaps agree then one can conclude that the reaction times to light and sound are for practical purposes independent, the calculated number of cases overlapping being based on this hypothesis.

Because of the considerable overlap theoretically possible between the normal or clinically fit, and those clinically unfit to drive, it is obvious that one cannot regard this upper limit of clinical fitness as the critical point for unfitness to drive or otherwise many grossly unfit drivers would escape detection. It is apparent that it is only with reaction times over the upper limit of clinical fitness that one could say definitely that a man must be unfit to drive on the basis of reaction times alone. One must therefore conclude, because of the wide variability of the readings, that it is undesirable to fix a definite upper limit for clinical fitness to drive to include all cases.

An alternative, and more effective method, is to establish the probability of a certain reaction time being recorded by men who are normal or who are clinically unfit to drive. If one could in evidence state that the accused had a reaction time such that it is 100 times more likely to be recorded by a drunken man than by a normal individual then, combined with the results of the clinical examination, it should aid the bench substantially in reaching a decision.

We must now consider the principle of arriving at a standard of clinical unfitness on the basis of reaction times alone. If a sufficiently large number of readings is available of the reaction times of both normal and clinically unfit subjects it is possible to draw the curve of distribution of the reaction times for each of these two classes. Each of these curves will conform, absolutely or nearly, to one of the numerous known types of such curves, and the values of x (reaction times) which would have any assigned probability (p) will be calculable to a sufficient degree of accuracy from the algebraical equation to the curve. If Y be the ordinate to the curve at the point x then p = Y.d.x. (where d is the minute base line x if there are innumerable readings on which the normal curve is constructed) and in comparing two curves the probabilities p_1 and p_2 will be proportional to Y_1 and Y_2 respectively.

Inspection of the histograms for normal individuals will show, as already pointed out above, that the distribution of reaction times approaches the "normal" form as might be expected from the general nature of biological variables, and from the not very small numbers examined. On the other hand the distribution of reaction times of the clinically unfit people is clearly not "normal" as it stands, nor could it be expressed in terms of one of the more usual distribution curves. This however is most probably due to the comparatively small number of cases available, and the principle which would guide us in determining the dividing line between clinically fit and clinically unfit, on the basis of reaction times alone, may be understood by constructing normal distributions of which the parameters ($\bar{x}$ and σ) are those actually found in the investigation just described. The operation consists in finding such a value of the reaction time that the chance of finding it in normal persons is very small as compared with the chance of its occurring in the clinically unfit. This however, entails a definition of the term "very small", and this is a matter on which the statistician as such can make no pronouncement. Calling this chance the likelihood of finding this value in either of the two populations specified by the parameters $\bar{x}$ and σ in the one case, and $\bar{x}^1$ and σ^1 in the other, the fraction $\frac{p(x)}{p_1(x^1)}$ is known as the relative likelihood. The expression $p(x)$ is to be read as "the probability of finding the given value in the population having $\bar{x}$ and σ as its parameters". If the relative likelihood (as defined above) is say 5 to 1, this does not mean that a man having the specified reaction time is five times more likely to be clinically fit than to be "drunk". It does mean that five times as many people would be expected to show that reaction time if they were drawn from the class of normal people (x) than if they were drawn from the class of the clinically unfit (x^1), and it is an axiom of interpretation that the hypothesis to be preferred is that which yields the greater relative likelihood. Where the dividing line is to be drawn is, as has been said above, a matter for somewhat arbitrary decision, but a relative likelihood of 100 to 1 would appear to be a reasonable value, if the hypothesis which requires the greater probability is that of clinical unfitness, and, as has been mentioned, the method of arriving at the value having this relative likelihood can be illustrated by assuming a normal distribution for both the groups.

For all curves of frequency drawn to the same scale, the ordinate Y corresponding to a value x in a variable having a standard deviation σ is given by the equation:-

$$Y = \frac{1}{\sigma\sqrt{2\pi}} \times \text{EXP.} - \tfrac{1}{2}\left(\frac{x - \bar{x}}{\sigma}\right)^2$$

Let there be another set of variables Y^1, x^1 and σ^1. Then, if the probability of a value in the curve of the second set of readings is equal to "a" times the probability of the same value occurring in the first set for equal values of x and x^1.

$$\frac{1}{\sigma^1\sqrt{2\pi}} \times \text{EXP} - \tfrac{1}{2}\left(\frac{x^1 - \bar{x}^1}{\sigma^1}\right)^2 = a\left\{\frac{1}{\sigma\sqrt{2\pi}} \times \text{EXP} - \tfrac{1}{2}\left(\frac{x - \bar{x}}{\sigma}\right)^2\right\}$$

$$\therefore\ a \times \text{EXP} - \tfrac{1}{2}\left(\frac{x - \bar{x}}{\sigma}\right)^2 = \frac{\sigma}{\sigma^1} \times \text{EXP} - \tfrac{1}{2}\left(\frac{x^1 - \bar{x}^1}{\sigma^1}\right)^2$$

and taking logarithms to the base e.

$$\text{Log}\,a - \frac{(x - \bar{x})^2}{2\sigma^2} = -\frac{(x^1 - \bar{x}^1)^2}{2\sigma^{1\,2}} + \log\sigma - \log\sigma^1$$

$$\therefore\ -\frac{(x - \bar{x})^2}{2\sigma^2} + \frac{(x^1 - \bar{x}^1)^2}{2\sigma^{1\,2}} = \log\sigma - \log\sigma^1 - \log a.$$

which is a quadratic equation in x from which x can be found, the quantities $\bar{x}^1$, $\bar{x}$, σ^1, σ, and log "a" being constants in this equation.

Then if x = normal reaction time to light (l)

$\bar{x}$ = normal mean reaction time to light (m)

x^1 = unfit reaction time to light (l_1)

$\bar{x}^1$ = unfit mean reaction time to light (m_1)

σ = standard deviation of normal reaction time to light (σ_1)

σ^1 = standard deviation of unfit reaction time to light (σ_{l_1})

$$-\frac{(l - m)^2}{2\sigma_1^2} + \frac{(l_1 - m_1)^2}{2\sigma^2_{l_1}} = \log \sigma_1 - \log \sigma_{l_1} - \log a$$

$$\therefore \frac{(l_1 - m_1)^2}{2\sigma^2 l_1} - \frac{(l - m)^2}{2\sigma^2{}_1} = \log \sigma_1 - \log \sigma_{l_1} - \log a$$

but by hypothesis $l = l_1$

$\therefore$ Final equation is:-

$$\frac{(l - m_1)^2}{2\sigma^2 l_1} - \frac{(l - m)^2}{2\sigma^2{}_1} = \log \sigma_1 - \log \sigma_{l_1} - \log a$$

By means of this equation the reaction time for any given relative likelihood can be calculated. The results are shown in Table xii, a selection of values for the likelihood ratio varying from 2 to 1, to 200 to 1, being quoted with their corresponding reaction times to light and sound.

Using the figures quoted in Table xiii, I constructed "normal probability curves" to the same scale for the normal and clinically unfit readings to a visual stimulus (Graph 3). It will be noted at once that the curve for the clinically unfit is much flatter than the curve of the normal readings and the area of overlap of the two curves already noted is obvious. The point where the curves intersect corresponds to a reaction time to light of 35.64 and at this point the ordinates of both groups are equal. As the probabilities are proportionate to the ordinates then it follows that at this point the corresponding reading on the abscissa might be obtained with equal probability from a normal or a clinically unfit individual. The value of this point of equal probability can be calculated from the equation above, and it has been found that for light the value is 35.64 and for sound 25.38 hundredths of a second. In the case of reaction time to light the difference between this figure (35.64) and the normal mean, in terms of the standard deviation, is 1.6, and the difference between it and the clinically unfit mean, in terms of σ, is 1.1. With regard to the reaction times to sound the difference between the "point of equal probability" (25.38) and the normal mean is 1.7σ, and between it and the clinically unfit mean is 0.51σ. These figures are therefore in every case less than 2σ above or below the normal and clinically unfit means.

As it has been arbitrarily decided that a reaction time which is 100 times more likely to be obtained from a man who is clinically unfit to drive than from one who is normal, is a reasonable critical point, it is interesting to note from the graph that the relative heights of the two ordinates at this point are of the order of 100 to 1. In the case of light this value is 42.71 and for sound 31.69 (Table xii).

It is interesting to observe the rate of increase in the reaction times to light and sound with increase in the probability ratio in favour of clinical unfitness to drive (Graphs 4 and 5). These graphs show that at first the curve rises steeply and then gradually flattens out. This means that above a certain value of the probability ratio any corresponding increase in the reaction time is comparatively small. The reaction times, of which the likelihood of the hypothesis of clinical unfitness is one hundred times greater than upon the hypothesis of normality, are in the near neighbourhood of the mean values of those found to be clinically unfit; they are just below in both cases (Tables ii and xii). Therefore it appears to be both mathematically reasonable and morally justifiable to class all those, whose reaction times in both cases are the same as or greater than the means, as clinically unfit on the basis of these tests alone.

It would of course, be highly inadvisable to accept the mean values given here as an actual basis from the medico-legal stand-point. The statistical constants, as well as the actual shape of the curve of distribution in clinical unfitness, clearly must be assessed from a much larger series of observations of which the present set is but the earliest part.

Until recently the comparison between the hypothesis of normality and clinical unfitness to drive would have been made by considering whether or not the reaction time lay within or beyond the interval $\bar{x}$ to $\bar{x} + 3\sigma$, those quantities being the parameters of the clinically normal population. This has the disadvantage that the alternative procedure, namely, enquiring whether the reading lay between the values $\bar{x}^1$ and $\bar{x}^1 - 3\sigma^1$, could lead to a doubtful interpretation of a value which lay in the neighbourhood of the average of the normal; for there was no criterion of exclusion between the two hypotheses in the region between the means of the two distributions. The present method does not admit the hypothesis of clinical unfitness until the relative likelihood of that hypothesis is quite considerable as judged by sporting standards (i.e., 100 : 1), and yet does provide a clear cut and easily understood point of division between the two classes. It is of interest however, to note that the dividing (or critical) value of the reaction time is of the order $\bar{x} + 3\sigma$ - these symbols referring to the normal population; and furthermore that it does lie in the neighbourhood of the clinically unfit mean values as determined in the present enquiry.

This happy agreement between the standard method and that adopted here makes it probable that more extended observations, which must be carried out elsewhere, may lead to the setting up of a reasonably certain critical value on which action could be taken.

The method used in this part of the analysis of the results is due to Professor P. J. Daniell, M.A.,Sc.D., of the Department of Mathematics of the University of Sheffield who has so far not published his observations in detail on the theory of criteria of this kind. I am deeply grateful to Professor Daniell for allowing me to use this method in my thesis as it presents a very useful practical solution to the problem of how to deal with values intermediate between the normal and the clinically unfit means.

Having demonstrated a practical method of assessing the reaction times of individuals under the influence of alcohol while in charge of a motor car, it is necessary to consider which of the physiological factors discussed above require to be allowed for in the practical consideration of a case.

In this connection it is necessary only to consider those variables which are correlated to reaction time to the extent of 0.5 or over. This being so only two factors arise for consideration, namely, age and the time since the last meal in their relationship to reaction time to an auditory signal. The regression line for the relationship between the two factors under review is drawn and then an ordinate is raised at the point corresponding to the clinically unfit mean reaction time to sound or the "100 to 1 point", whichever is selected as the standard of unfitness to drive. In this case the 100 : 1 point has been chosen (Graphs 10 and 11).

Consider first the graph for the sound/hours since last meal relationship (Graph 9). It will be seen that the regression line does not cut the ordinate at the "100 to 1 point", and it can therefore be concluded that in practice the correlation between the reaction time to sound and the number of hours since the last meal has no bearing on the case and can be ignored.

The position in regard to the age/reaction time to sound relationship is rather different. Graph 10 shows that the critical line cuts the regression line at a point representing on the ordinates just over 48 years. This indicates that the factor of age may have to be allowed for in considering the question of reaction time to sound in older men who are thought to be unfit to drive because of alcoholic intoxication. If, as appears from the graph, there is a definite practical bearing of age on reaction time to sound, then one would expect that the probability of a man having a reaction time normally equal to or greater than that obtained when the probability of its occurring amongst clinically unfit men is 100 times greater than amongst normal men (i.e., 31.69 hundredths of a second) would increase proportionately with age. To investigate this point I regrouped the normal readings for men over 36 years in a correlation table (Table xiv) taking age as one basis of grouping and reaction times to sound as the other. I then calculated the total number in each age group with a reaction time to sound equal to or over the critical level and assessed the percentage probability of this happening for each age group. Graph 11 shows the result. It indicates that with increased age there is no consistent rise in the probability of obtaining a reaction time to sound equal to or greater than 31.69 (likelihood ratio $\frac{U}{N} = 100$) in normal subjects, and therefore the relatively high correlation between reaction time to sound and age in older men can in practice be ignored. It is admitted that only 84 subjects were investigated from this point of view, but, while if very large numbers were considered there might be some alteration in the shape of the graph, the number examined is large enough to show the general trend. In any case this factor of age does not have a practical bearing on reaction time to light, and as I recommend that both reaction times be taken, and the two reaction times are for practical purposes independent, then in a doubtful case where only the reaction time to sound is found to be above the critical level in a subject over 45 years of age the accused would, in the presence of satisfactory clinical evidence, be given the benefit of the doubt.

The important point to be emphasised is that the use of reaction times as a test for fitness to be in charge of a mechanically propelled vehicle would not stand alone as evidence but would be used as an additional test to support the clinical examination.

I would suggest that the reaction time should be taken at the commencement of the examination. The reason is that this test need only occupy about five minutes while the clinical examination may take anything from 30 to 45 minutes. During this time the subject's condition may change very appreciably, and if the reaction time is the final test then an abnormally low result may be obtained which does not at all reflect his condition at the time of arrest.

In all cases the reaction times to both visual and auditory stimuli should be recorded because both are important in driving a motor car and they are largely independent. If both tests are found to be above the critical level then this greatly multiplies the probability in favour of unfitness to drive. If, for example, it is found that the accused has reaction times to both light and sound which are such that it is 100 times more likely to have obtained these from an individual who is clinically unfit to drive than from one who is normal then, because the two reaction times are independent or largely so, the likelihood of the hypothesis is increased from 100 to 1 to 10,000 to 1.

If it is possible to take the accused's reaction times when he has recovered from the effects of the alcohol, and I found that most of those I examined in connection with actual cases readily submitted to this, then of course additional evidence is obtained on which to work. The readings made at the time of arrest can be used for calculating the probabilities discussed above. His normal reading will indicate whether or not he ordinarily has a reaction time approaching the mean for normal individuals as already established. In addition it will be possible to calculate the relative increase in his reaction time due to alcohol, and to estimate how this compares with the mean relative increase in persons known to be clinically unfit to drive, making due allowance for normal variability.

In actual practice it may be found that individuals will fall into three categories. The first includes those where both reaction times are above the critical level, the second where they are below, and the third those who have one reaction time above and the other below. The question of how to deal with this latter group need not give rise to much difficulty as a consideration of all the available evidence will enable one to reach a fair conclusion. In any case the relative probability of the readings obtained being recorded by either a normal or a clinically unfit man will be quoted to the court and the bench will draw its own conclusions.

(7) SUMMARY OF PERSONAL OBSERVATIONS AND CONCLUSIONS. APPARATUS, CHOICE OF SUBJECTS, EXPERIMENTAL METHODS, CLINICAL EFFECTS AND SUBJECTIVE SENSATIONS.

Using the d'Arsonval clock to record the reaction times to visual and auditory stimuli, I studied the effects of alcohol and of physiological variables on reaction times.

I utilised 178 male subjects, varying in age from 17 to 53 years - 168 of these were volunteers and the remainder were accused of being "drunk in charge of a car". Some men recorded only a single set of readings to each stimulus while others supplied as many as 21 sets under different conditions.

Efforts to obtain a suitable masking medium for the alcohol were made but no satisfactory solution was discovered, so I did not attempt to disguise the fact that alcohol was an ingredient of the test beverage.

Twenty men under 30 years of age, over 5 feet 10 inches in height, and between 11 and 12 stones in weight, were used first and, after 10 days practice, were given varying doses of alcohol under standard conditions.

The remaining forty-one subjects, chosen at random, were not allowed any practice so that their results would correspond to those obtained in everyday life. These men were also subjected to standard conditions as to diet and sleep before the experiment. All the subjects while under the influence of alcohol were tested clinically as to fitness to drive before each recording. To obtain a knowledge of the alcoholic history of each subject he was asked to fill in a questionnaire. This information was used in determining the most suitable dose, but it was found that, even with the history as a guide, it was nearly impossible to predict the effect a particular volume of alcohol would have.

The effects of fatigue were studied on the normal readings of the subjects who were also used for the alcohol experiments, and in addition on 16 men who attended specially for this purpose morning and evening for four or five days in succession. In all 423 observations on this aspect of the problem were obtained.

Eighty-six men, varying in age from 37 to 53 years, were used specifically to find the effect of age on reaction time in middle life.

Analysis of the subjective sensations experienced shows that a feeling of fatigue and a desire to sleep were the most common. Dizziness, inability to concentrate, and visual disturbances were the next most common subjective experiences in the order stated. Eight men had a transient feeling of well-being. Rapidity of regression of the alcoholic effects was particularly noted. Half an hour may make a great difference. A marked absence of the traditional psychological changes produced by alcohol was observed under experimental conditions.

Physiological Aspects of the Results.

Five hundred and nine readings under normal conditions were recorded to visual and auditory stimuli. The mean reaction times to light and sound are 28.86 and 19.19 respectively. The readings are scattered over a considerable range but the distribution corresponds closely to the "normal" curve. While the range is relatively wide the standard deviations are comparatively small, $\sigma_l = 4.25$ and $\sigma_s = 3.63$.

Coefficient of variation for reaction time to light = 14.7. Coefficient of variation for reaction time to sound = 18.8. It appears therefore that the reaction time to sound is rather more variable than the reaction time to light. The true mean values of the universe sampled lie between 28.48 and 29.24 in the case of light, and between 18.87 and 19.51 in the case of sound.

The coefficient of correlation between the reaction times to light and sound is +0.428. The two quantities are therefore only partially dependent on one another and, as one reaction time does not directly reflect changes in the other, both must be considered in assessing degree of intoxication.

For men between 17 and 37 years the coefficient of correlation between reaction time to sound and age is

+0.142. This is a low correlation and of no practical importance. Over the age of 37 this coefficient becomes +0.62 which represents a fair degree of correlation, and in effect it means that over the age of 37 an increase in age is accompanied by some increase in reaction time to sound.

The coefficient of correlation between reaction time to light and age is +0.25 for the whole group, and +0.27 for the older men. This is a low degree of correlation and is of no importance practically. Fatigue was estimated on the basis of the number of hours since rising. Using a series of 423 observations, taken from 83 individuals and covering periods up to 21½ hours since rising, I found 'r' for the sound/fatigue relationship to be -0.02 and for the light/fatigue relationship -0.073. This means that ordinary degrees of fatigue do not influence reaction times.

The state of the alimentary canal was assessed in terms of the number of hours since the last meal. This variable was studied in a series of 242 observations. Where m = hours since the last meal, $r_{sm} = -0.58$, and $r_{lm} = -0.08$. The former indicates moderate correlation, while the latter is not significant and can be ignored. It appears that a full stomach influences, to some extent, at least, the reaction time to sound, the relationship being inverse, but has no effect on reaction time to light.

Achievement of an established normal reaction time as a result of practice was not found to be possible. Using the numerical order of the reading (n) to indicate the amount of practice, and considering 383 observations, I found $r_{ln} = -0.21$. This is four times the standard error and is therefore significant though it represents a low degree of correlation. $r_{sn} = -0.033$ and is not significant. The different degrees to which practice affects the reaction times to light and sound may be due to the more complex visual paths in the brain as compared with those for sound. It can be concluded that practice on this particular machine has no appreciable effect on reaction time, and one can afford to ignore it.

The Effect of Alcohol on Reaction Times.

This problem was studied in 215 observations. The mean values of the alcohol readings (both clinically fit and unfit to drive) were 37.50 for light and 26.30 for sound, as against the normal means of 28.86 and 19.19. It is apparent that alcohol increases the reaction times to visual and auditory stimuli. An apparent decrease in reaction time to light was noted when dilute alcohol was taken. A tendency in the same direction was produced by the ingestion of an equal volume of water and may be due to the fluid bulk alone. Dilute alcohol tended to increase the reaction time to sound while water had no definite effect on this at all.

It is clear from a study of the first 20 subjects who were given alcohol that the effect is most marked 60 to 90 minutes following ingestion, the greatest number of subjects showing the maximum change at one hour. In the light of this it is not surprising to find that in the case of a proportion of the men who were allowed no practice the highest reading was the first recorded, i.e., one hour after ingestion. The low coefficient of correlation between reaction time and practice proves that this initial high reading was not due to lack of practice, as might be thought, and in any case the first 20 subjects eliminated this factor during their first ten daily attendances.

The reaction times of those clinically fit to drive compare quite favourably with the normal readings. Omitting the abnormal extreme readings the reaction times of those clinically unfit to drive were 44.77 and 32.32 to light and sound respectively, which is a substantial increase on the normal. In these men the variability of the readings was also increased due to impaired powers of continuous concentration.

Alcohol also increases the range of the readings and there is a considerable overlap of the normal and the clinically unfit recordings.

The reaction times of individuals clinically unfit to drive are not "normally" distributed, possibly due to the relatively small numbers considered.

With the extreme readings omitted it was found that alcohol, in amount sufficient to produce unfitness to drive, led to an average relative increase in reaction time to light and sound of 14.28 and 11.94 hundredths of a second respectively. The differences between the normal mean, the means of those fit to drive, and the average reading of men unfit to drive clinically are 12.7 and 9.4 times the standard error of the difference between the means in the case of light, and 6.4 and 5.3 times in the case of sound. It can be deduced from this that these differences are very unlikely to have arisen by chance.

Under the influence of alcohol r_{ls} becomes +0.947. This means that in normal people the reaction times for light and sound are partially independent, while, on the other hand, they are so highly correlated in those who were known to have taken appreciable quantities of alcohol that their relationship is completely represented by a straight line graph. In an individual under the influence of alcohol it would thus be theoretically possible to forecast one reaction time from a knowledge of the other using the graph. However, the coefficient falls to +0.855 and to +0.54 when the extreme readings are omitted, in those subjects judged unfit to drive. Therefore this theoretical method would only indicate alcoholic intake and could not be used practically in assessing the degree of drunkenness. However, at all stages of alcoholic intoxication the correlation between reaction times to light and sound is higher than in normal people.

Medico-legal Applications of the Results.

A person's reaction time is of great practical importance in driving and its increase due to alcohol is a possible practical index of an individual's fitness to drive. In these experiments fitness to drive was assessed on the basis of the recommended clinical tests. Owing to the considerable overlap of the normal and the clinically unfit readings it would be unfair to conclude that anyone with a reaction time over the mean of those clinically fit to drive was in the category of those unfit to drive due to alcohol.

Using the mean $\pm$ 3σ as the standard, the extent of the overlap (i.e., lower limit of clinical unfitness to upper limit of clinical fitness) extends from 19.75 to 51.59 for light and from zero to 32.14 in the case of sound. If these upper limits were set as the critical level then many persons actually and manifestly unfit to drive would escape because of the extreme width of the overlap area. Nevertheless these upper limits must be accepted before one could certify definitely that a person is clinically unfit on the basis of reaction times alone. Because of the considerable variability of the readings of people in both categories it is therefore impracticable on this basis to fix an upper limit of clinical fitness to embrace all cases.

A more effective method is to establish the probability of a certain reaction time being recorded by men who are normal or who are clinically unfit to drive.

The critical level is arbitrarily fixed at those reaction times to light and sound which are 100 times more likely to be obtained from a man who is clinically unfit to drive than from one who is normal. This value for light is 42.71 and for sound 31.69. Above a certain value of the probability ratio any corresponding increase in reaction time is relatively small.

The reaction times of which the likelihood of the hypothesis of clinical unfitness is 100 times greater than upon the hypothesis of normality are in the near neighbourhood of the mean values of those who were clinically unfit. It is of interest to note that the dividing or critical value of the reaction times is of the order of $x + 3\sigma$, these symbols referring to the normal population. Therefore it appears to be both mathematically reasonable and morally justifiable to class all those, whose reaction times in both cases are the same as, or greater than, the means as unfit to drive, on the basis of these tests alone.

It would of course be unwise to use the levels quoted above as an actual basis from the medico-legal standpoint. A much larger series of cases would have to be analysed by a professional statistician but I have illustrated the method and have given an estimate of the value of the critical point.

Only two variables have coefficients of correlation with reaction times over 0.5. These are "hours since the last meal" and age, in relation to reaction time to sound. These two factors, and all those less closely correlated, can in practice be ignored in considering the effect of alcohol on reaction times.

Both reaction times should be recorded as if each is above the critical point, this greatly multiplies the probability in favour of unfitness to drive.

The recommended procedure is to take the accused's reaction times when arrested and again later after he has recovered from the effects of the alcohol. The initial sets of readings can be used for calculating the probabilities discussed above. His second test will indicate whether or not he ordinarily has a reaction time approaching the mean for normal individuals, as already established. In addition it will be possible to calculate the relative increase in reaction time due to alcohol, and to estimate how this compares with the mean relative increase in persons known to be clinically unfit to drive.

Based on the work described in this thesis my submission is that in the changes in reaction time produced by the ingestion of alcohol we have a practical method for testing whether or not a person is so far under the influence of alcohol as to be unfit to have proper control of a mechanically propelled vehicle. The reaction time is capable of accurate measurement, and it provides a mathematical index of the probability of sobriety or unfitness to drive which will supply a definite need at present existing, in enabling the medical witness to supplement his opinion based on clinical tests with a measurement on which the court can form its own conclusions.

As already pointed out it is not desirable to accept rigidly the critical levels arrived at in this work based as they are on relatively small numbers. The observations would have been considerably extended but war conditions made it impossible to obtain adequate supplies of alcohol to pursue the matter further. In any case it is desirable that these experiments, with this apparatus, should be repeated by other workers in different parts of the country if an impressive mass of material suitable for the attentions of a professional statistician is to be collected, on which definite critical points for unfitness to drive are to be established.

(8) ACKNOWLEDGEMENTS.

The experimental work described in this thesis was carried out with material provided by the City of Sheffield Watch Committee and I wish to make grateful acknowledgement of the facilities provided. My thanks are due also to Group Captain G. Struan Marshall, Officer Commanding, Central Medical Establishment, Royal Air Force, through whose good offices I was able to obtain on loan the d'Arsonval clock used. To the officers and men of the City of Sheffield Police Force, who so willingly attended for the experiments in their off-duty time, I am very indebted. Without their willing co-operation the work could not have been undertaken.

Sergeant R. R. McK. Young and Police Constable L. R. Wood of the Traffic Department prepared the fair copies of the graphs and Detective Sergeant F. Wallington of the Photographic Department of the City of Sheffield Police Force was responsible for the photographs of the apparatus. To these officers I acknowledge my indebtedness.

My thanks are due to Professor P. J. Daniell, M.A., Sc.D., of the Mathematics Department, Sheffield University for allowing me to use a statistical method devised by him and on the theory of which he is about to publish a paper. This method greatly enhances the value of my work from the practical point of view.

During the analysis of my figures Professor M. A. MacConaill, M.B.,Ch.B.,B.A.O.,M.Sc., of the Department of Anatomy, University College, Cork, and formerly Lecturer in Anatomy at Sheffield University made many useful suggestions and was always willing to advise me on the choice of statistical methods. To Professor MacConaill I am especially indebted and I gratefully acknowledge his never failing kindness and patience.

BIBLIOGRAPHY.

1. Accident Proneness Among Motor Drivers. Ind. Hlth. Res. Brd. Report. No. 84. 1939.

2. Alcohol - its action on the human organism. Report of the Medical Research Council. London. 1917.

3. Alcohol - its action on the human organism. Report of the Medical Research Council. London. 1938.

4. Baxter and Travis. The Reaction Time to Vestibular Stimuli. J. Exper. Psychol. 22. p. 277. 1938.

5. Bellis, C. J. Reaction Times and Chronological Age. Proc. Soc. Exper. Biol. & Med. 30. p. 810. 1933.

6. Bogen, E. Drunkenness. A Quantitative Study of Acute Alcoholic Intoxication. J.A.M.A. 89. p. 1509. 1927.

7. Cheney, R. H. Comparative Effect of Caffeine per se and a Caffeine Beverage (coffee) upon the Reaction Time in Normal Young Adults. J. Pharmac. & Exper. Thèrap. 53. p. 304. 1935.

8. Cheney, R. H. Reaction Time Behaviour after Caffeine and Coffee Consumption. J. Exper. Psychol. 19. p. 357. 1936.

9. Comrie, L. J. Barlow's Tables. E. & F.N.Spon. London. 1941.

10. De Silva, H. R. On an Investigation of Driving Skill. The Human Factor. 10 (1). p. 1. 1936.

11. Dietl and von Vintschgau. Arch. f. d. ges. Physiol. 16. p. 316. 1878.

12. Dodge, R. and Benedict, F. G. Psychological Effects of Alcohol. Carnegie Institution of Washington. 1915.

13. Dürig. Pflügers Archiv. f. d. ges. Physiol. 113. p. 314. 1906.

14. Exner. Archiv. f. d. ges. Physiol. 7. p. 601. 1873.

15. Fairlie, W. M. Road Safety and Alcohol. The Third Rae Memorial Lecture. 1937.

16. Fisher, R. A. Statistical Methods for Research Workers. Biological Monographs and Manuals. 1932.

17. Fisher and Yates. Statistical Tables for Biological, Agricultural and Medical Research. Oliver and Boyd. 1938.

18. Frank, C. W. Science News Letter. May 19th, 1934.

19. Goodenough, F. L. The Development of Reactive Processes from Early Childhood to Maturity. J. Exper. Psych. 18. p. 431. 1935.

20. Hall, J. Drunkenness as a Criminal Offence. J. Crim. Law & Criminol. 32(3). p. 297. 1941.

21. Heise, H. A. and Halporn, B. Medico-legal Aspects of Drunkenness. The Pennsylvania Med. J. 36(3). p. 190. 1932.

22. Hill Bradford, A. Principles of Medical Statistics. The Lancet. London. 1937.

23. Hyde, Spray and Howat. Am. J. Physiol. 31. p. 309. 1912/13.

24. Jetter, W. W. Studies in Alcohol 1. The Diagnosis of Acute Alcoholic Intoxication by Correlation of Clinical and Chemical Findings. Am. J. M. Sc. 196. p. 475. 1938.

25. Jetter, W. W. Studies in Alcohol 2. Experimental Feeding of Alcohol to Non-alcoholic Subjects. Am. J. M. Sc. 196. p. 487. 1938.

26. Jonnard, R. and Maire, L. The Influence of Some Ordinary Substances on the Visual Reaction Time to an Auditory Signal. Paris Med. 2. p. 273. 1933.

27. Kleitman, Titelbaum and Feiveson. The Effect of Body Temperature on Reaction Time. Am. J. Physiol. 121. p. 495. 1938.

28. Kraepelin. Phil. Stud. 1. p. 573. 1883.

29. McDougall, W. and Smith, M. The Effect of Alcohol and Some Other Drugs during Normal and Fatigued Conditions. Medical Research Council Special

Report Series. No. 56. 1920.

30. Meihuizen. Arch. f. d. ges. Physiol. 7. p. 201. 1873.

31. Mellanby, E. Alcohol, its Absorption into and Disappearance from the Blood under Different Conditions. Medical Research Council Special Report Series. No. 31. 1919.

32. Miles, W. R. Effect of Alcohol on Psycho-physiological Functions. Carnegie Institution of Washington. 1918.

33. Miles, W. R. Alcohol and Human Efficiency. Carnegie Institution of Washington. 1924.

34. Muchlberger, C. W. The Effect of Alcohol on Driving Skill. J.A.M.A. 115(25). p. 2199. 1940.

35. Newman, H. and Fletcher, E. The Effect of Alcohol on Driving Skill. J.A.M.A. 115(19). p. 1600. 1940.

36. Report of Committee on Tests for Drunkenness. British Medical Association. 1927.

37. Rugg, H. O. Statistical Methods Applied to Education. The Riverside Press. Cambridge U.S.A. 1917.

38. Rutherford. Proc. Roy. Soc. Edin. 20. p. 328. 1893.

39. Sachsenberg. Alcohol and Safe Driving. Munch. Med. Woch. 11th March, 1938.

40. Soltau, H. K. V. Tests for Drunkenness. Med. Press & Circ. No. 5317. p. 280. April 2nd, 1941.

41. Smith, S. and Stewart, C. P. Diagnosis of Drunkenness from the Excretion of Alcohol. B.M.J. 1. p. 87. January 16th, 1932.

42. Smith, S. and Glaister, J. Recent Advances in Forensic Medicine. J. & A. Churchill. London. 1939.

43. Stone's Justices' Manual. Ed. Dingle F.B. Butterworth & Co. London. 1942.

44. Travis, L. E. and Dorsey, J. M. Effects of

Alcohol on the Patellar Tendon Reflex Time. Arch. Neurol. & Psychiat. 21. p. 613. 1929.

45. Tuttle, W. W. The Effects of Alcohol on the Patellar Tendon Reflex. J. Pharmac. & Exper. Therap. 23. p. 163. 1924.

46. Varé, G. and P., Verdier, H., and Videcovitch, M. The Influence of Alcohol on the Threshold of the Psycho-motor Centres. Compt. rendu Soc. de Biol. 103. p. 1255. 1930.

47. Varé, P. The Influence of Alcohol on Psycho-motor Reactions. Compt. rendu Soc. de Biol. 111. p. 70. 1932.

48. Vernon, H. M. The Influence of Alcohol on Manual Work and Neuro-muscular Co-ordination. Medical Research Council Special Report Series No. 34. 1919.

49. Vernon, H. M. The Relation of Alcohol to Road Accidents: a preliminary study. The Human Factor. 10. p. 253. 1936.

50. Warren. J. Physiol. 8. p. 311. 1887.

51. Zwahlen, L. Contribution a l'étude de l'action de l'alcool sur l'excitabilité cérébral et l'activité psychique. Thèse Paris. 1933.

THE EFFECT OF ALCOHOL ON PSYCHO-MOTOR REACTIONS, STUDIED PARTICULARLY FROM THE MEDICO-LEGAL ASPECT.

Volume 2.

by

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THESIS OFFERED FOR THE

DEGREE

of

M.D. GLASGOW

C O N T E N T S

VOLUME 2.

APPENDIX 1.

GRAPHS

APPENDIX 1.

(GRAPHS).

GRAPH 1. Histogram showing the distribution of the normal reaction times to light, and the distribution of the readings of those clinically unfit to drive.

GRAPH 2. Histogram showing the distribution of the normal reaction times to sound, and the distribution of the readings of those clinically unfit to drive.

GRAPH 3. Normal probability curves of normal and clinically unfit readings for light.

GRAPH 4. Curve of likelihood ratio $\left(\frac{U}{N}\right)$ in relation to reaction time for light.

GRAPH 5. Curve of likelihood ratio $\left(\frac{U}{N}\right)$ in relation to reaction time for sound.

GRAPH 6. Regression line for light and sound - normal readings.

GRAPH 7. Regression lines for light and sound - normal and clinically unfit readings.

GRAPH 8. Regression line for "sound/light" relationship in normal subjects and those under the influence of alcohol.

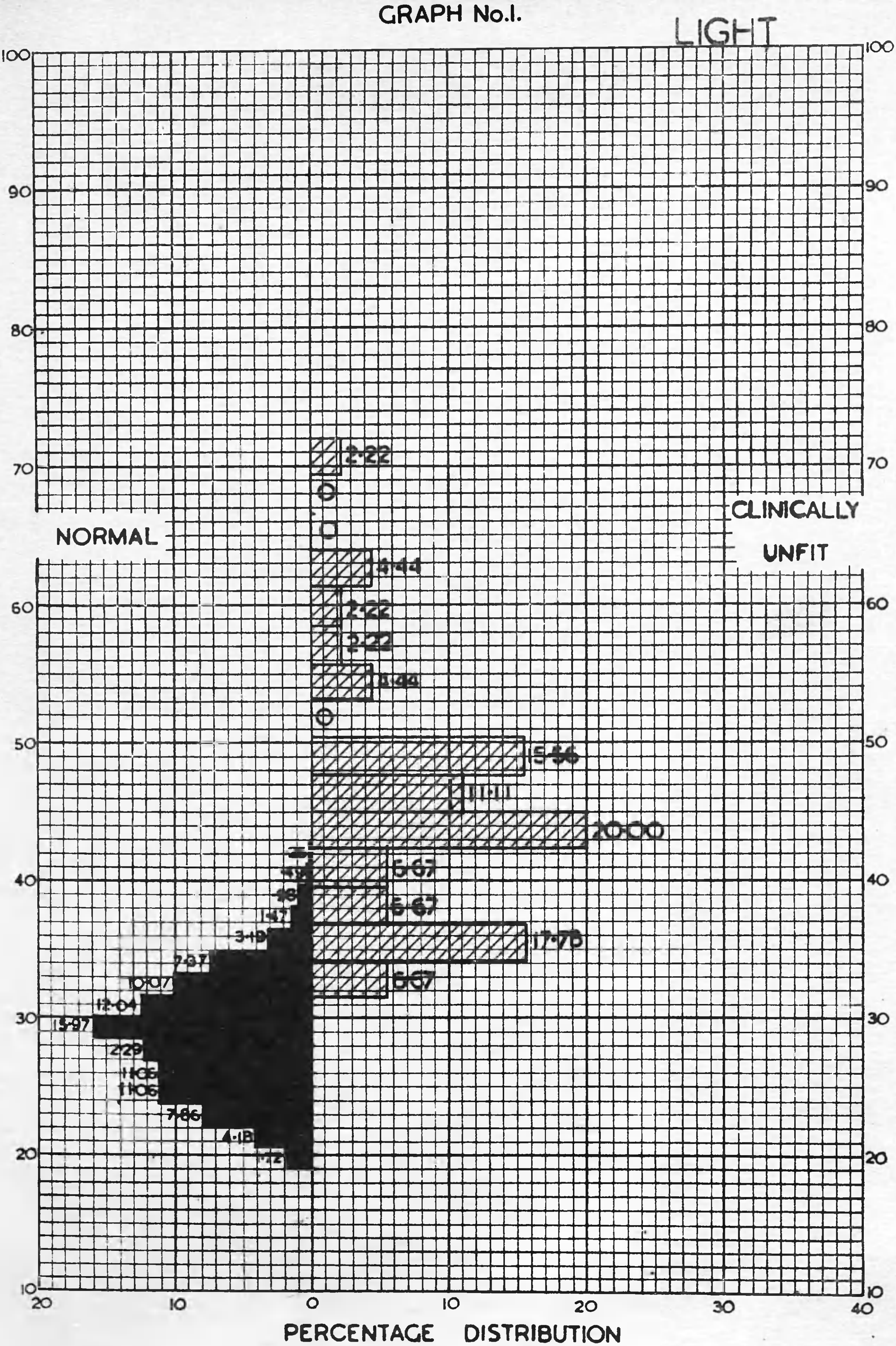
GRAPH 9. Regression line for sound/"hours since last meal" relationship.

APPENDIX 1 (Continued).

(GRAPHS)

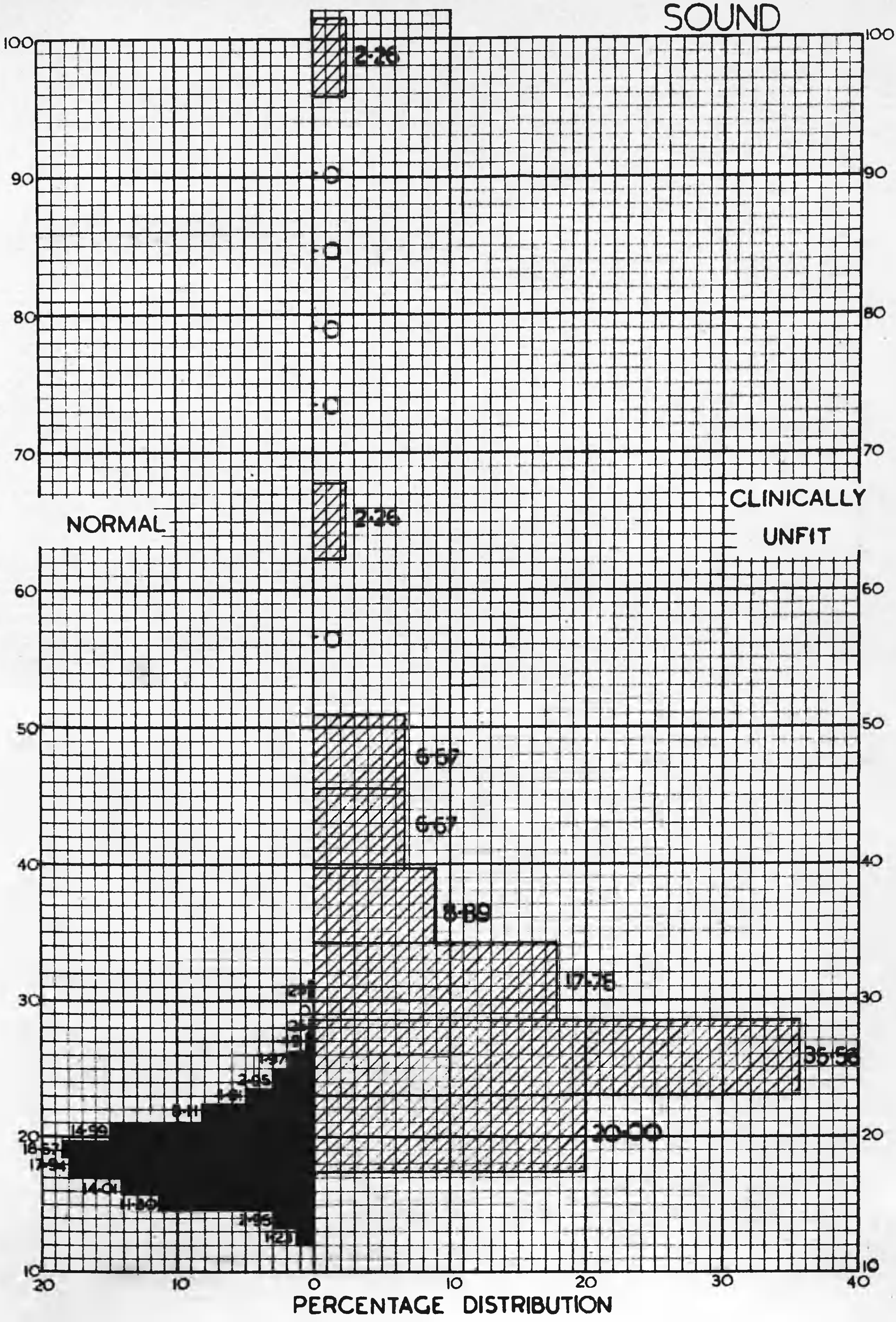
GRAPH 10. Regression line for "sound/age" relationship.

GRAPH 11. Graph showing the probability of obtaining a reaction time to sound equal to or greater than 31.69 (likelihood ratio $\frac{U}{N} = 100$) in normal subjects from 37 to 53 years of age.

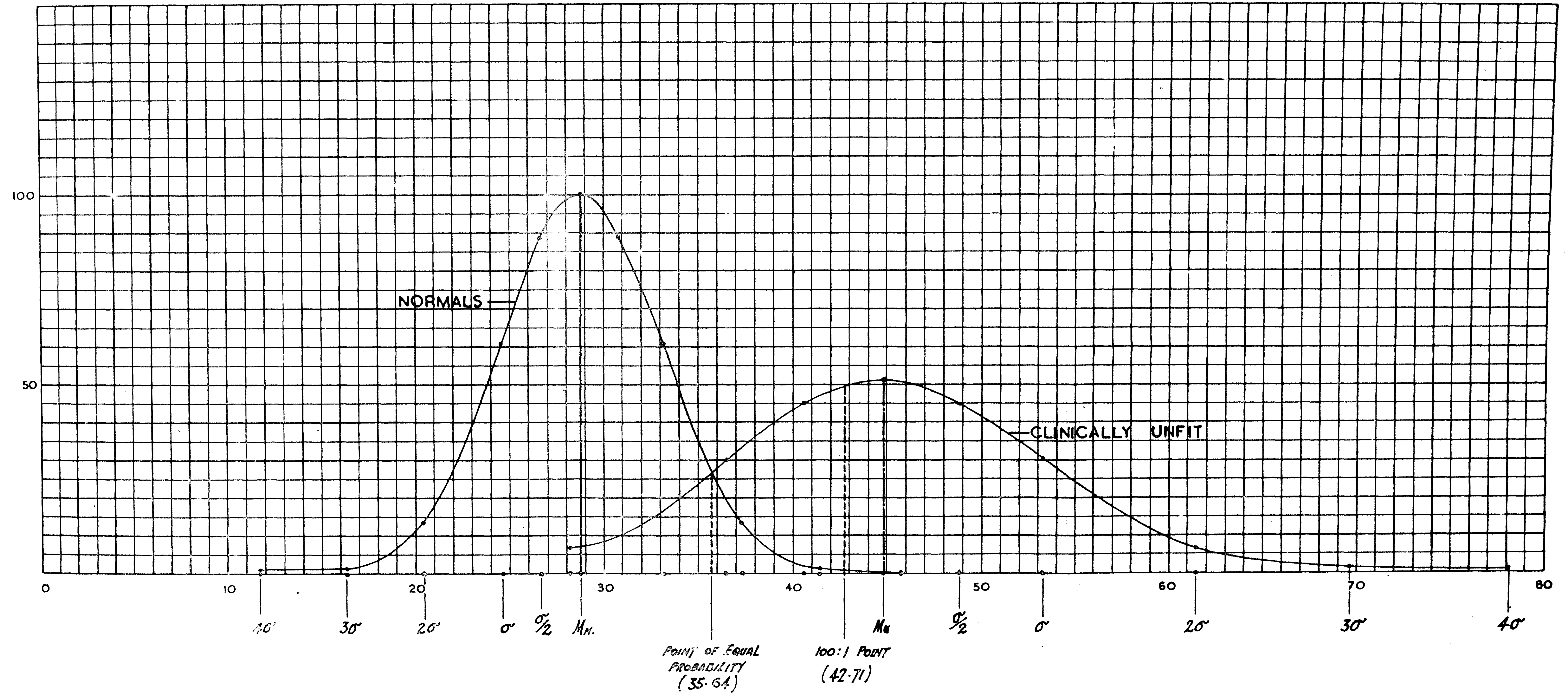


GRAPH No.1.
LIGHT
NORMAL
CLINICALLY
UNFIT
PERCENTAGE DISTRIBUTION
2·22
4·44
2·22
2·22
4·44
15·56
11·11
20·00
6·67
6·67
17·78
6·67
15·97
12·04
10·07
7·37
3·19
1·47
2·29
11·06
11·06
7·86
4·18

GRAPH No.2.


SOUND
NORMAL
CLINICALLY
UNFIT
2·26
2·26
6·57
6·67
8·89
17·75
35·56
20·00
8·11
14·99
14·01
1·97
2·95
2·95
PERCENTAGE DISTRIBUTION
100
90
80
70
60
50
40
30
20
10
20
10
0
10
20
30
40

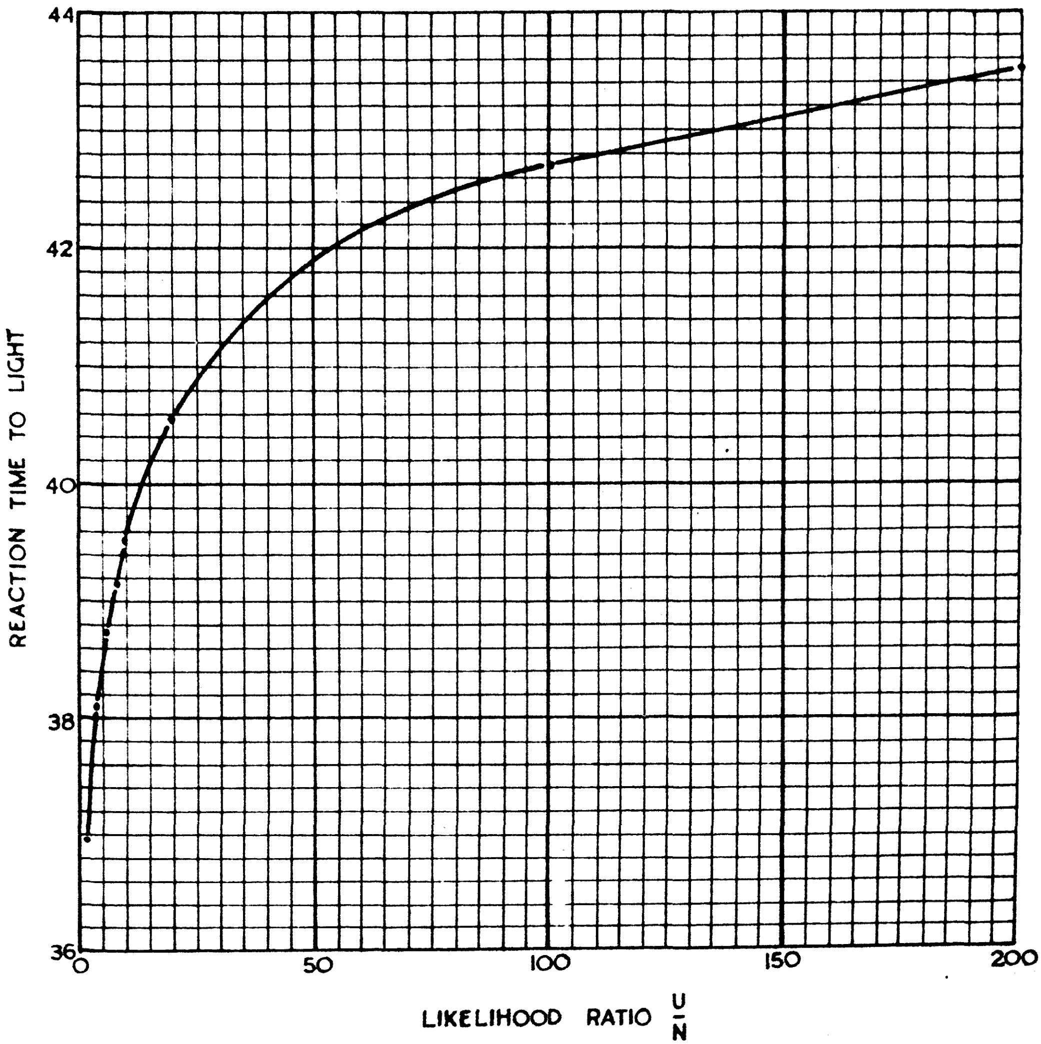
GRAPH No.3.



NORMAL PROBABILITY CURVES OF NORMAL AND CLINICALLY UNFIT READINGS FOR LIGHT.

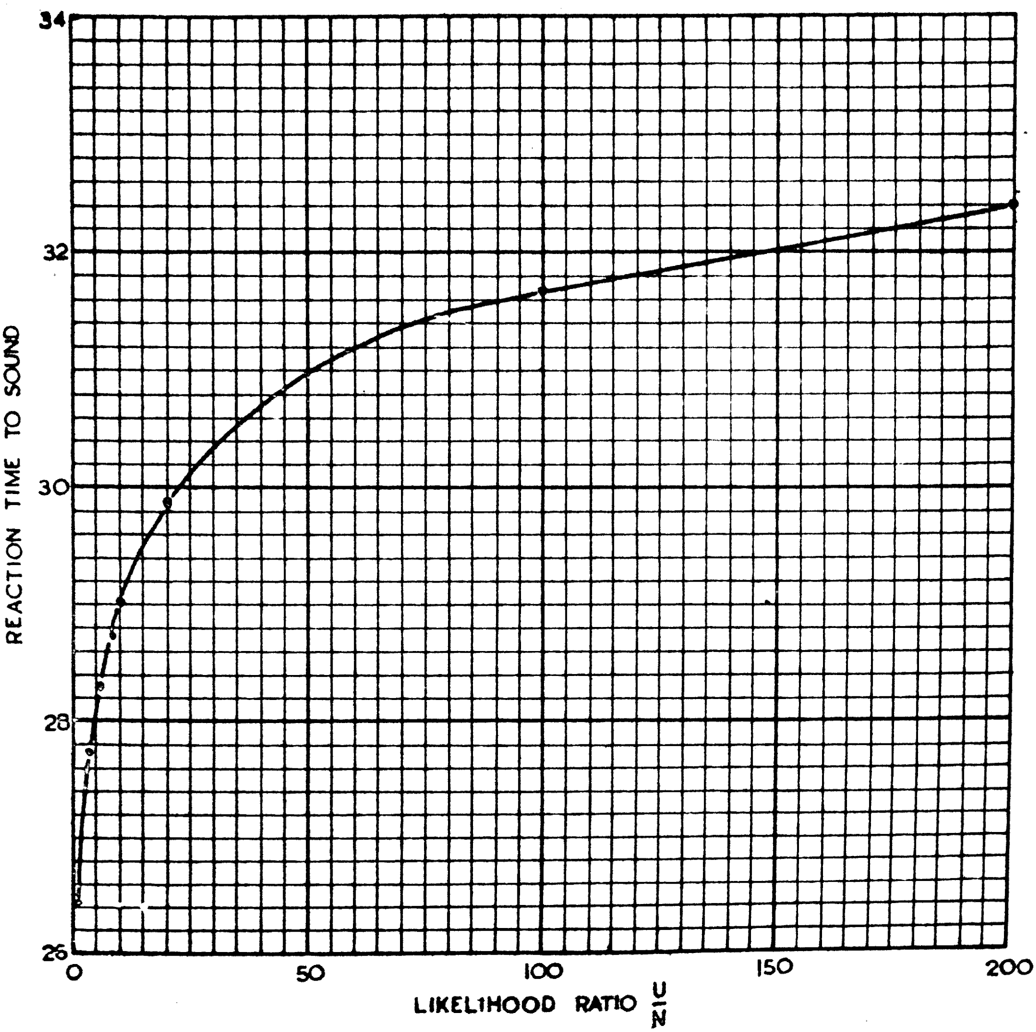
GRAPH No.4.

CURVE OF LIKELIHOOD RATIO IN RELATION TO REACTION TIME FOR LIGHT.



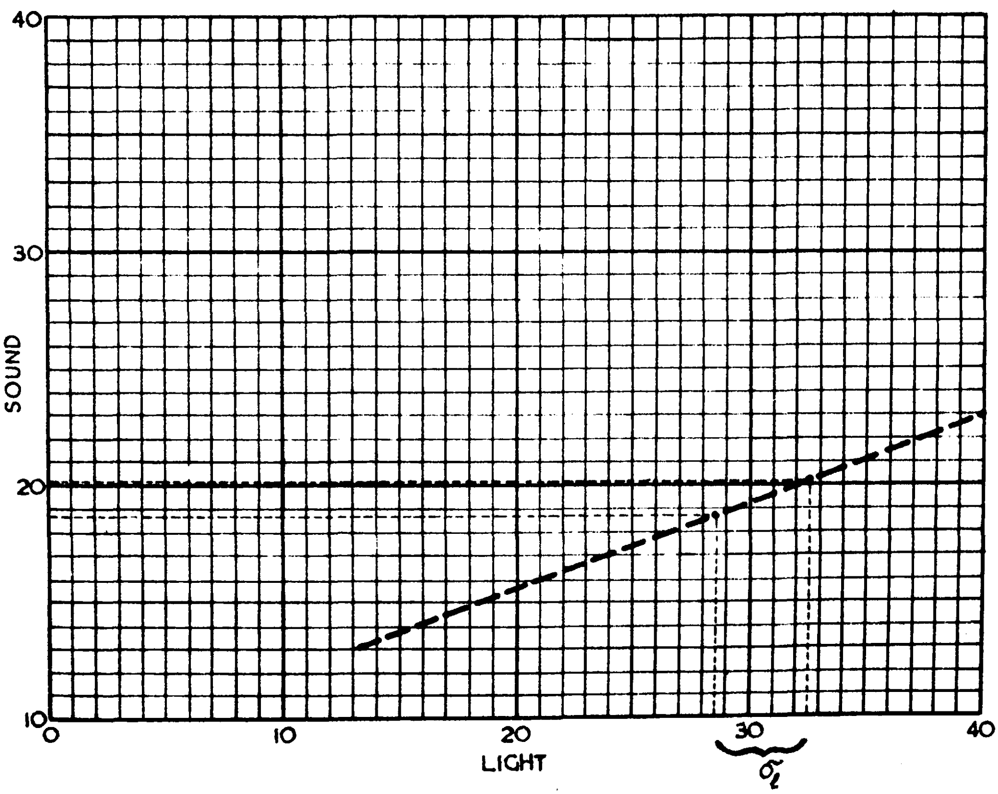
GRAPH No.5.

CURVE OF LIKELIHOOD RATIO IN RELATION TO REACTION TIME FOR SOUND.

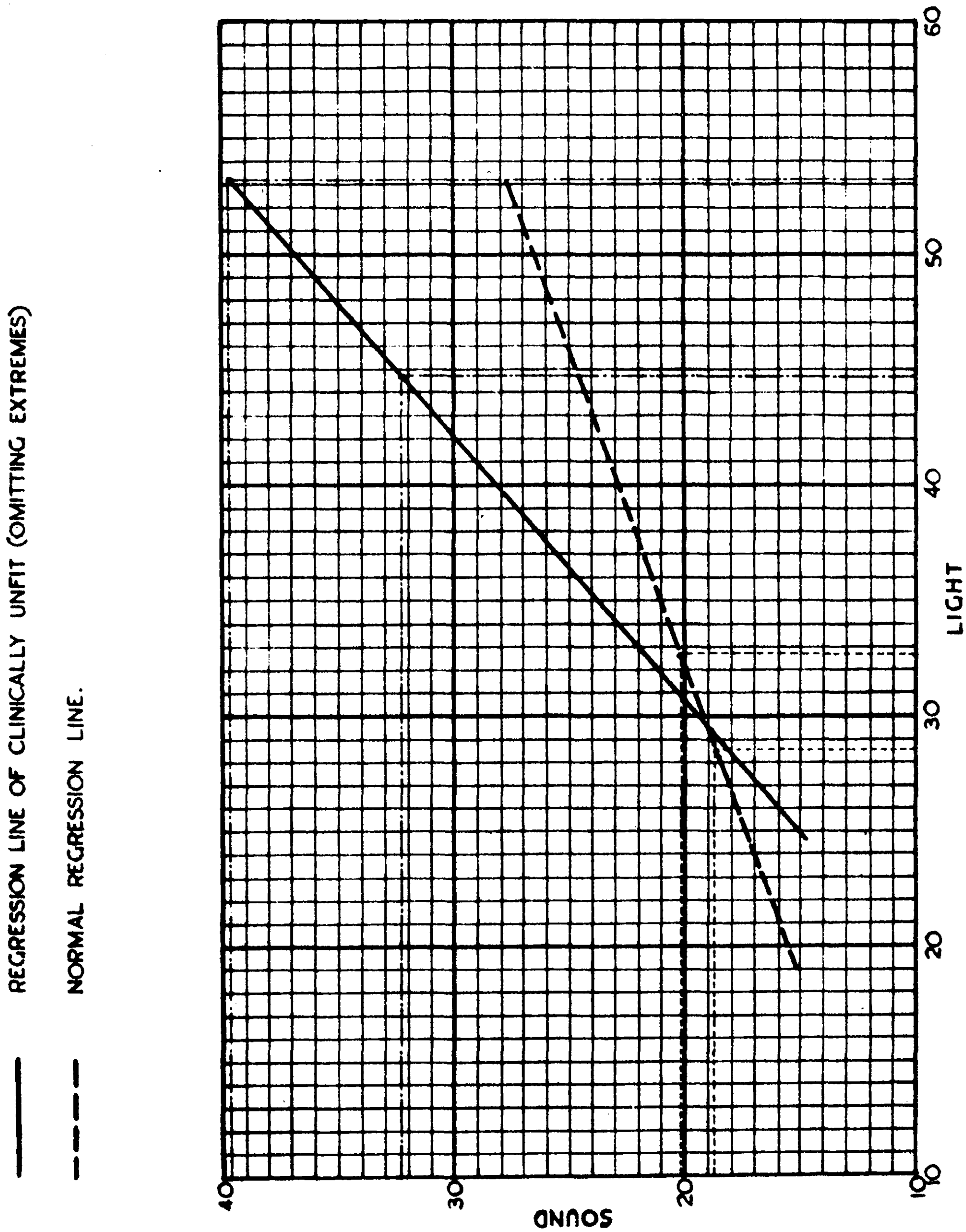


GRAPH No. 6.

REGRESSION LINE FOR LIGHT & SOUND
(NORMAL)

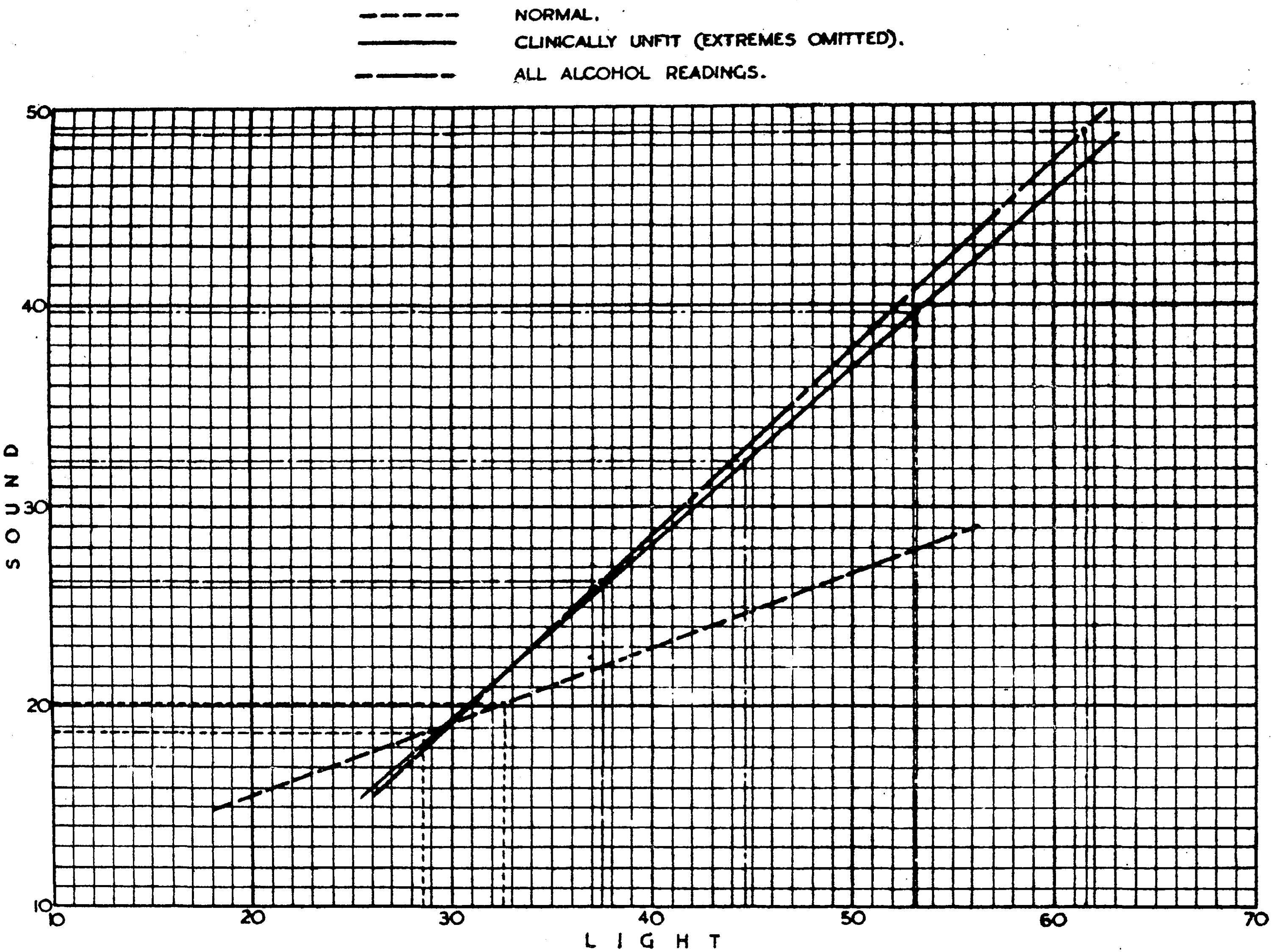


GRAPH No.7.



REGRESSION LINES FOR LIGHT & SOUND
(NORMAL & CLINICALLY UNFIT)

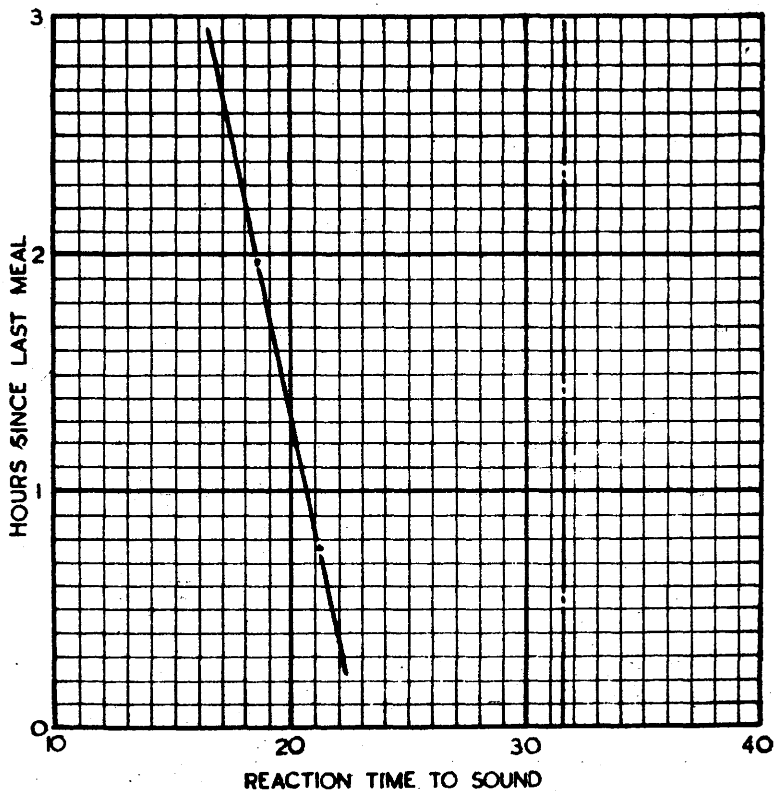
GRAPH No.8.



REGRESSION LINES FOR SOUND/LIGHT RELATIONSHIP IN NORMAL SUBJECTS & SUBJECTS UNDER THE INFLUENCE OF ALCOHOL.

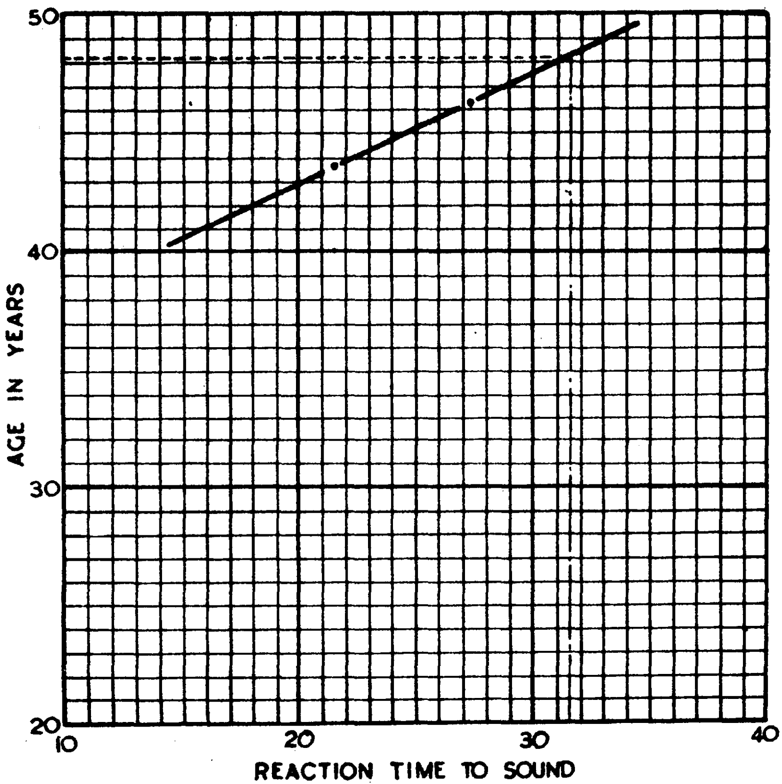
GRAPH No. 9.

REGRESSION LINE FOR SOUND / HOURS SINCE LAST MEAL RELATIONSHIP.



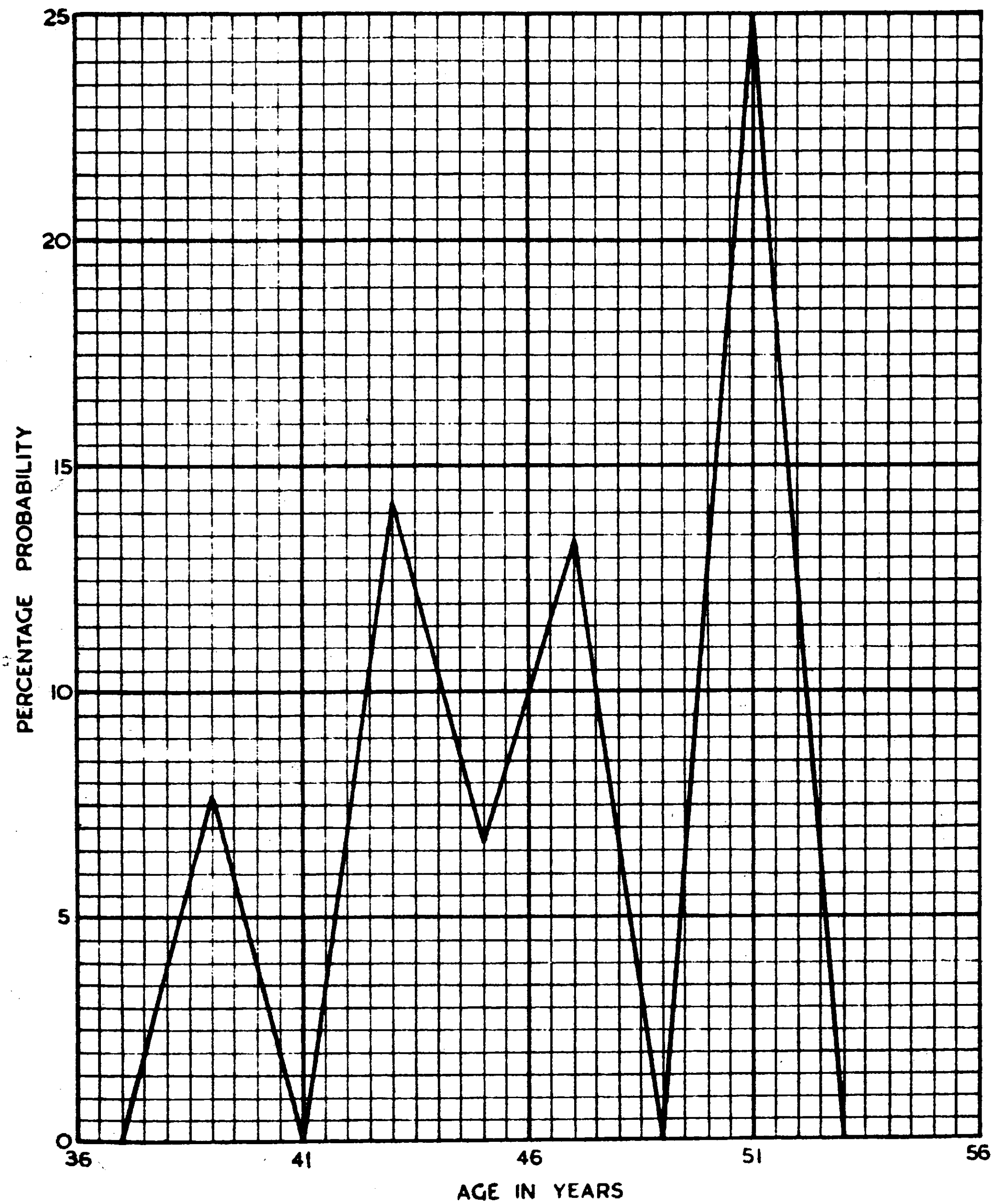
GRAPH No. 10.

REGRESSION LINE FOR SOUND/AGE RELATIONSHIP.



GRAPH No.11.

GRAPH SHOWING PROBABILITY OF OBTAINING A REACTION TIME TO SOUND EQUAL TO OR GREATER THAN 31·69 (LIKELIHOOD RATIO $\frac{U}{N}$ = 100) IN NORMAL SUBJECTS FROM 37 TO 53 YEARS OF AGE.



A P P E N D I X 2.

TABLES i to xiv

SUMMARY OF STATISTICS

APPENDIX 2.

(SUMMARY OF STATISTICS).

TABLE i.	Normal Readings and Coefficients of Correlation.
TABLE ii.	Alcohol readings and abnormal coefficients of correlation.
TABLE iii.	Relative increase due to alcohol.
TABLE iv.	Range of Readings.
TABLE v.	Coefficients of Variation.
TABLE vi.	Standard errors.
TABLE vii.	Standard Error of the difference between the Means.
TABLE viii.	Regression Equations.
TABLE ix.	Standard Errors of Correlation Coefficients.
TABLE x.	Comparison of Normal and Unfit Readings omitting extreme readings.
TABLE xi.	Alcohol readings - clinically fit to drive.
TABLE xii.	Likelihood ratio and reaction times.
TABLE xiii.	Quantities required for constructing "normal probability curves" of normal and clinically unfit readings for light.
TABLE xiv.	Table showing distribution of Reaction time to sound for age groups from 37 to 53 years.

TABLE 1.

Normal Readings.

Number of readings	Mean age	R.T.	Mean	σ
407	27.28	Light	28.64	3.94
84	43.78	Light	29.97	5.675
18	40.22	Light	28.58	2.68
102	43.16	Light	29.72	5.22
509	30.46	Light	28.86	4.25
407	27.28	Sound	18.80	2.94
84	43.78	Sound	21.56	5.67
18	40.22	Sound	16.66	1.46
102	43.16	Sound	20.69	5.53
509	30.46	Sound	19.19	3.63

Normal Coefficients of Correlation.

Coefficient of correlation between:-	Number of observations	r
Sound and light	407	+ 0.428
Sound and age (17 - 37 years)	407	+ 0.142
Sound and age (37 - 53 years)	84	+ 0.62
Sound and age (17 - 53 years)	509	+ 0.34
Light and age (17 - 37 years)	407	+ 0.321
Light and age (37 - 53 years)	84	+ 0.27
Light and age (17 - 53 years)	509	+ 0.25
Sound and hours since rising	423	- 0.02
Sound and hours since last meal	242	- 0.58
Sound and numerical order of reading	383	- 0.033
Light and hours since rising	423	- 0.073
Light and hours since last meal	242	- 0.08
Light and numerical order of reading	383	- 0.21

TABLE ii.

Alcohol Readings.

State	Number of readings	R.T.	Mean	σ
Both fit and unfit clinically	215	Light	37.50	24.16
Clinically unfit	48	Light	56.1	44.86
Clinically unfit (extreme omitted)	45	Light	44.77	8.34
Clinically fit	167	Light	32.15	6.48
Both fit and unfit clinically	215	Sound	26.30	23.65
Clinically unfit	48	Sound	43.50	48.05
Clinically unfit (extreme omitted)	45	Sound	32.34	13.74
Clinically fit	167	Sound	21.31	3.61

Abnormal Correlation Coefficients.

Correlation coefficient between:-	Number of observations	r
Sound and light (Both fit and unfit)	215	+ 0.947
Sound and light (Clinically unfit)	48	+ 0.855
Sound and light (Clinically unfit extreme omitted)	45	+ 0.54
Light and age (Both fit and unfit)	215	+ 0.021

TABLE iii.

Relative Increase due to Alcohol.

Clinically fit to drive	Light (D_1-E_1)	Sound (D_s-E_s)	Variation σ_1	σ_s
Mean (51)	4.53	3.20	3.63	3.103
Clinically unfit to drive				
Mean (20)	23.37	20.98	40.31	40.67
Clinically unfit to drive (one extreme reading omitted)				
Mean (19)	14.28	11.97	6.47	7.60

Extreme reading. Light 195.9 Difference from mean=181.62

This difference is 28.07 times the standard deviation.

Sound 192.1 Difference from mean=180.13

This difference is 23.7 times the standard deviation. Therefore the readings in the extreme case are exceptional as they are more than twice the standard deviation removed from the mean.

TABLE iv.

Range of Readings.

1. Normal.

Reaction.	Mean.	Range.	Mean age.	Range of ages.
Light	28.64	19.0 to 42.3	27.28	17 to 37
(407)				
Sound	18.80	12.1 to 30.4		
Light	29.97	21.1 to 47.6	43.78	37 to 53
(84)				
Sound	21.56	13.2 to 43.2		
Light	28.86	19.0 to 47.6	30.46	17 to 53
(509)				
Sound	19.19	12.1 to 43.2		

2. All Alcohol Readings.

Reaction.	Mean.	Range.
Light	37.5	19.4 to 244.8
(215)		
Sound	26.30	15.1 to 240.9

3. Alcohol Readings - Clinically Unfit to Drive.

Reaction.	Mean.	Range.
Light	56.1	31.6 to 244.8
(48)		
Sound	43.5	17.7 to 240.9

4. Relative Increase due to Alcohol - Clinically Fit to Drive.

Reaction.	Mean.	Range.
Light	4.53	-3.50 to +13.1
(51)		
Sound	3.20	-3.50 to +13.1

5. <u>Relative Increase due to Alcohol - Clinically Unfit to Drive.</u>

Reaction.	Mean.	Range.
Light (20)	23.37	+4.9 to +195.9
Sound	20.98	+3.7 to+192.1

6. <u>Relative Increase due to Alcohol - Clinically Unfit Omitting Extreme Reading.</u>

Reaction.	Mean.	Range.
Light (19)	14.28	+4.9 to 30.3
Sound	11.97	+3.7 to 34.4

TABLE v.

Coefficient of Variation.

State.	Reaction.	Mean.	Standard deviation σ	Coefficient of variation.
Normal 17 to 37 yrs. 407 readings	Light	28.64	3.94	13.8
	Sound	18.80	2.94	15.6
Normal 37 to 53 yrs. 84 readings	Light	29.97	5.675	18.9
	Sound	21.56	5.670	26.3
Under alcohol all readings 215 readings	Light	37.5	24.16	64.4
	Sound	26.30	23.65	89.9
Clinically unfit due to alcohol 48 readings	Light	56.1	44.86	79.9
	Sound	43.5	48.05	110.5
Clinically fit to drive. Relative increase due to alcohol 51 readings	Light	4.53	3.63	80.1
	Sound	3.20	3.103	96.9
Clinically unfit to drive. Relative increase due to alcohol 20 readings	Light	23.37	40.31	172.5
	Sound	20.98	40.67	193.8
Normal 17 to 53 yrs. 509 readings	Light	28.86	4.25	14.7
	Sound	19.19	3.63	18.8
Clinically unfit to drive. Relative increase due to alcohol (extreme reading omitted) 19 readings	Light	14.28	6.47	45.3
	Sound	11.97	7.60	63.5

(Cont. Coefficient of Variation).

State.	Reaction.	Mean.	Standard deviation σ	Coefficient of variation.
Clinically fit to drive 167 readings	Light	32.15	6.47	20.1
	Sound	21.31	3.61	16.9
Clinically unfit (extreme readings omitted) 45 readings	Light	44.77	8.34	18.6
	Sound	32.34	13.74	42.5

TABLE vi.

Standard Error.

State.	Reaction.	Mean.	σ	Standard error $\left(\frac{\sigma}{\sqrt{2n}}\right)$ of σ	Standard error $\left(\frac{\sigma}{\sqrt{n}}\right)$ of mean.
Normal 17 to 37 yrs. 407 readings	Light	28.64	3.94	0.14	0.19
	Sound	18.80	2.94	0.10	0.15
Normal 37 to 53 yrs. 84 readings	Light	29.97	5.675	0.44	0.62
	Sound	21.56	5.670	0.44	0.62

True Mean for Universe Sampled is Within Limits of Estimated Mean ± 2 x Standard Error.

State.	Reaction.	Mean.	True Mean.	True σ
Normal 17 to 37 yrs. 407 readings	Light	28.64	28.26 to 29.02	3.66 to 4.22
	Sound	18.80	18.50 to 19.10	2.74 to 3.14
Normal 37 to 53 yrs. 84 readings	Light	29.97	28.73 to 31.21	4.795 to 6.555
	Sound	21.56	20.32 to 22.80	4.79 to 6.55

State.	Reaction.	Mean.	σ	Standard error of σ	Standard error of mean
Clinically unfit due to alcohol 48 readings	Light	56.1	44.86	4.58	6.47
	Sound	43.5	48.05	4.90	6.93

Standard Errors (cont.)

State.	Reaction.	Mean.	σ	Standard error of σ	Standard error of Mean.
Clinically unfit (omitting extreme reading) 45 readings	Light	44.77	8.34	0.88	1.24
	Sound	32.34	13.74	1.45	2.05

State.	Reaction.	Mean.	True Mean.	True σ
Clinically unfit (omitting extreme reading) 45 readings	Light	44.77	42.29 to 47.19	6.58 to 10.10
	Sound	32.34	28.24 to 36.44	10.84 to 16.64

TABLE vii.

Standard Error of the Differences between the Means.

State.	Reaction.	σ	Number of readings.	Standard error of differences.
Normal	Light	3.94	407	Light 6.48
	Sound	2.94		
Clinically unfit due to alcohol	Light	44.86	48	Sound 6.94
	Sound	48.05		

State.	Reaction.	σ	Number of readings.	Standard error of differences.
Normal	Light	4.25	509	Light 1.257
	Sound	3.63		
Clinically unfit (omitting extreme readings)	Light	8.34	45	Sound 2.057
	Sound	13.74		

State.	Reaction.	σ	Number of readings.	Standard error of differences.
Clinically fit	Light	6.47	167	Light 1.34
	Sound	3.61		
Clinically unfit (omitting extreme readings)	Light	8.34	45	Sound 2.07
	Sound	13.74		

TABLE viii.

Regression Equations.

	Mean l	Mean t	Equation
Reaction time to light with age (407)	28.64	27.28	$l = 0.278\ t + 21.06$
Reaction time to light with age (84)	29.97	43.78	$l = 0.3834\ t + 13.18$
Reaction time to light with age (509)	28.86	30.46	$l = 0.14\ t + 24.6$
	Mean s	Mean t	Equation
Reaction time to sound with age (407)	18.8	27.28	$s = 0.091\ t + 16.32$
Reaction time to sound with age (84)	21.56	43.78	$s = 0.88\ t - 16.97$
Reaction time to sound with age (509)	19.19	30.46	$s = 0.16\ t + 14.32$
	Mean l	Mean h	Equation
Reaction time to light with hours since rising (423)	28.6	4.9	$l = -0.0743h + 28.96$
	Mean s	Mean h	Equation
Reaction time to sound with hours since rising (423)	18.7	4.9	$s = -0.0142h + 18.77$
	Mean l	Mean m	Equation
Reaction time to light with hours since last meal (242)	27.91	1.97	$l = -0.15704m + 28.22$
	Mean s	Mean m	Equation
Reaction time to sound with hours since last meal (242)	18.45	1.97	$s = -0.7424m + 19.91$
	Mean l	Mean n	Equation
Reaction time to light with numerical order of reading (383)	28.22	5.42	$l = -0.294\ n + 29.81$
	Mean s	Mean n	Equation
Reaction time to sound with numerical order of reading (383)	18.72	5.42	$s = -0.032\ n + 18.89$

TABLE ix.

Standard Errors of Correlation Coefficients.

Coefficient of Correlation between:-	Number of observations	r	Standard error of r $\left(\frac{1}{\sqrt{n-1}}\right)$
Sound and light	407	+0.428	±0.0496
Sound and age (17 to 37 yrs.)	407	+0.142	±0.0496
Light and age (17 to 37 yrs.)	407	+0.321	±0.0496
Sound and age (37 to 53 yrs.)	84	+0.62	±0.109
Light and age (37 to 53 yrs.)	84	+0.27	±0.109
Sound and light (alcoholic)	215	+0.947	±0.068
Light and age (alcoholic)	215	+0.021	±0.068
Sound and light (clinically unfit)	48	+0.855	±0.146
Sound and light (clinically unfit, extreme omitted)	45	+0.54	±0.151
Sound and hours since rising	423	-0.02	±0.049
Light and hours since rising	423	-0.073	±0.049
Sound and hours since last meal	242	-0.58	±0.064
Light and hours since last meal	242	-0.08	±0.064
Sound and numerical order of reading	383	-0.033	±0.051
Light and numerical order of reading	383	-0.21	±0.051
Sound and age (17 to 53 yrs.)	509	+0.34	±0.044
Light and age (17 to 53 yrs.)	509	+0.25	±0.044

TABLE x.

Comparison of Normal and Unfit Readings Omitting Extreme Readings.

State	Number of readings	Mean light (l)	Mean sound (s)	σ_l	σ_s
Normal (17 to 53)	509	28.86	19.19	4.25	3.63
Unfit to drive due to alcohol (1 omitted)	45	44.77	32.34	8.34	13.74

Omitted Alcoholic Readings.

	Light	Sound
Omitted readings	244.8	208.4
	216.6	184.0
	217.5	240.9
Deviation of readings from mean	200.03	176.06
	171.83	151.66
	172.73	208.56
Deviation in units of standard deviation	24.0	12.9
	20.6	11.04
	20.7	15.2

Lower limit of clinical unfitness (if readings normally distributed).

Mean l − 3 σ_l = 44.77 − 3 x 8.34 = 19.75

Mean s − 3 σ_s = 32.34 − 3 x 13.74 = −8.88

Therefore lower limit of clinical unfitness = Light: 19.75
Sound: −8.88

TABLE xi.

Alcohol Readings - Clinically fit to Drive.

Number of readings	Mean l	Mean s	σ_1	σ_s
167	32.15	21.31	6.48	3.61

Upper limits of clinical fitness.

Light Mean + 3 σ_1 = 32.15 + 3(6.48) = 32.15 + 19.41 = 51.59

Sound Mean + 3 σ_s = 21.31 + 3(3.61) = 21.31 + 10.83 = 32.14

	Lowest reading clinically unfit	Number of normals above this
Light	35.3	0
Sound	20.6	5

Therefore $\frac{0}{19} \times \frac{5}{19}$ = 0 readings overlap in both

Actual number of readings overlapping in both 0.

Therefore the two reactions are for practical purposes independent.

Reaction time such that the probability of getting it in normal people is x times greater than in clinically unfit people.

Likelihood ratio $\frac{n}{u}$ (x.)	Light	Sound
2	34.19	22.85
4	32.5	21.69
6	31.36	19.12
8	30.41	15.50
10	29.56	14.51
20	25.83	12.43
100	14.8	9.32
200	10.19	8.27

TABLE xiii.

Quantities Required for Constructing Normal Probability Curves of Normal and Clinically Unfit Readings for Light.

Normal $\sigma = 4.25$ Abnormal $\sigma = 8.34$

Normal	x −	x +	x − mean	$\frac{x - \text{mean}}{\sigma}$	Normal ordinates Υ	Abnormal ordinates $(\Upsilon \times \sigma_n/\sigma_u)$	Abnormal (unfit)	x −	x +
mean	28.86	-	0	0	1	0.5096	mean	44.77	-
$\sigma/2$	26.73	30.99	2.13	0.50	0.88250	0.44972	$\sigma/2$	40.60	48.94
σ	24.61	33.11	4.25	1	0.60653	0.30909	σ	36.43	53.11
2σ	20.36	37.36	8.50	2	0.13534	0.06897	2σ	28.09	61.45
3σ	16.11	41.61	12.75	3	0.01111	0.00566	3σ	19.75	69.79
4σ	11.86	45.86	17.0	4	0.00034	0.00017	4σ	11.41	78.13

The value of Υ was obtained from Table ii in "Statistical Methods Applied to Education", Rugg, H.O. The Riverside Press, Cambridge, U.S.A. 1917, p. 388.

TABLE xiv.

Table showing Distribution of Reaction Time to Sound for Age Groups from 37 to 53 years.

Reaction Time to Sound	AGE 36-37.9	38-39.9	40-41.9	42-43.9	44-45.9	46-47.9	48-49.9	50-51.9	52-53.9
13-15.9		1	2	3	2	1			
16-18.9	2	5	2	2	4	5	3		
19-21.9	1	5	3	3	3	2	1	1	1
22-24.9			2	3	2	4	2	1	2
25-27.9				1	3		1	1	1
28-30.9		1				1			
31-33.9				1					
34-36.9		1		1		2			
37-39.9					1				
40-42.9									
43-45.9								1	
Totals	3	13	9	14	15	15	7	4	4
Probability	$\frac{0}{3}$	$\frac{1}{13}$	$\frac{0}{9}$	$\frac{2}{14}$	$\frac{1}{15}$	$\frac{2}{15}$	$\frac{0}{7}$	$\frac{1}{4}$	$\frac{0}{4}$
Percentage Probability	0	7.7	0	14.3	6.7	13.4	0	25	0

APPENDIX 3.

TABLES xv to xxv

DETAILED FIGURES

APPENDIX 3.

(DETAILED FIGURES)

TABLE xv.	Normal readings of men between the ages of 17 and 37 years, and mean values of all the normal readings.
TABLE xvi.	Normal readings from 84 men between the ages of 37 and 53 years.
TABLE xviA.	Normal readings from 2 men between the ages of 37 and 53 years, and the mean values for all the normal readings in this age group.
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TABLE xxv.	Tables showing the calculation of the standard deviation of the reaction times to light and sound by grouping.

T A B L E xv.

NORMAL READINGS OF MEN BETWEEN THE AGES OF 17 and 37 YEARS, AND MEAN VALUES OF ALL THE NORMAL READINGS.

Table xv Normal Readings of Men Between 17 and 37.

Subject's number	Age (t)	t^2	R.T. to light (l)	l^2	t + l	$(t + l)^2$	R.T. to sound (s)	s^2	s + t	$(s + t)^2$	s + l	$(s + l)^2$
1000	32	1024	32.3	1043.29	64.3	4134.49	19.0	361.00	51.0	2601.00	51.3	2631.69
	32	1024	26.2	686.44	58.2	3387.24	14.7	216.09	46.7	2180.89	40.9	1672.81
	32	1024	27.6	761.76	59.6	3552.16	15.7	246.49	47.7	2275.29	43.3	1874.89
	32	1024	26.2	686.44	58.2	3387.24	16.5	272.25	48.5	2352.25	42.7	1823.29
	32	1024	23.5	552.25	55.5	3080.25	16.9	285.61	48.9	2391.21	40.4	1632.16
	32	1024	23.5	552.25	55.5	3080.25	14.8	219.04	46.8	2190.24	38.3	1466.89
	32	1024	25.3	640.09	57.3	3283.29	15.8	249.64	47.8	2284.84	41.1	1689.21
	32	1024	25.7	660.49	57.7	3329.29	16.3	265.69	48.3	2332.89	42.0	1764.00
	32	1024	30.8	948.64	62.8	3943.84	15.7	246.49	47.7	2275.29	46.5	2162.25
	32	1024	26.5	702.25	58.5	3422.25	17.0	289.00	49.0	2401.00	43.5	1892.25
130	25	625	34.6	1197.16	59.6	3552.16	18.3	334.89	43.3	1874.89	52.9	2798.41
239	28	784	33.7	1135.69	61.7	3806.89	19.0	361.00	47.0	2209.00	52.7	2777.29
678	23	529	31.9	1017.61	54.9	3014.01	19.1	364.81	42.1	1772.41	51.0	2601.00
156	23	529	31.5	992.25	54.5	2970.25	24.7	610.09	47.7	2275.29	56.2	3158.44
261	27	729	29.9	894.01	56.9	3237.61	21.0	441.00	48.0	2304.00	50.9	2590.81
20	25	625	29.3	858.49	54.3	2948.49	19.7	388.09	44.7	1998.09	49.0	2401.00

Subject's number	Age (t)	t^2	R.T. to light (l)	l^2	t + l	$(t + l)^2$	R.T. to sound (s)	s^2	s + t	$(s + t)^2$	s + l	$(s + l)^2$
531	24	576	28.3	800.89	52.3	2735.29	20.4	416.16	44.4	1971.36	48.7	2371.69
	24	576	29.7	882.09	53.7	2883.69	18.3	334.89	42.3	1789.29	48.0	2304.00
	24	576	27.8	772.84	51.8	2683.24	17.1	292.41	41.1	1689.21	44.9	2016.01
	24	576	32.0	1024.00	56.0	3136.00	19.7	388.09	43.7	1909.69	51.7	2672.89
280	24	576	27.8	772.84	51.8	2683.24	16.3	265.69	40.3	1624.09	44.1	1944.81
	24	576	24.8	615.04	48.8	2381.44	17.3	299.29	41.3	1705.69	42.1	1772.41
	24	576	25.3	640.09	49.3	2430.49	18.4	338.56	42.4	1797.76	43.7	1909.69
	24	576	27.3	745.29	51.3	2631.69	19.3	372.49	43.3	1874.89	46.6	2171.56
	24	576	26.0	676.00	50.0	2500.00	18.0	324.00	42.0	1764.00	44.0	1936.00
	24	576	23.9	571.21	47.9	2294.41	17.8	316.84	41.8	1747.24	41.7	1738.89
	24	576	26.8	718.24	50.8	2580.64	18.2	331.24	42.2	1780.84	45.0	2025.00
	24	576	26.4	696.96	50.4	2540.16	17.1	292.41	41.1	1689.21	43.5	1892.25
	24	576	24.3	590.49	48.3	2332.89	18.2	331.24	42.2	1780.84	42.5	1806.25
	24	576	27.5	756.25	51.5	2652.25	17.2	295.84	41.2	1697.44	44.7	1998.09
	24	576	25.6	655.36	49.6	2460.16	17.0	289.00	41.0	1681.00	42.6	1814.76
221	25	625	32.7	1069.29	57.7	3329.29	19.1	364.81	44.7	1998.09	51.8	2683.24
	25	625	27.3	745.29	52.3	2735.29	19.0	361.00	44.0	1936.00	46.3	2143.69

Subject's number	Age (t)	t^2	R.T. to light (l)	l^2	t + l	$(t + l)^2$	R.T. to sound (s)	s^2	s + t	$(s + t)^2$	s + l	$(s + l)^2$
221	25	625	28.8	829.44	53.8	2894.44	21.9	479.61	46.9	2199.61	50.7	2570.49
	25	625	30.1	906.01	55.1	3036.01	21.2	449.44	46.2	2134.44	51.3	2631.69
	25	625	31.1	967.21	56.1	3147.21	22.0	484.00	47.0	2209.00	53.1	2819.61
	25	625	30.2	912.04	55.2	3047.04	23.0	529.00	48.0	2304.00	53.2	2830.24
	25	625	28.2	795.24	53.2	2830.24	20.4	416.16	45.4	2061.16	48.6	2361.96
	25	625	26.2	686.44	51.2	2621.44	18.3	334.89	43.3	1874.89	44.5	1980.25
	25	625	29.2	852.64	54.2	2937.64	20.7	428.49	45.7	2088.49	49.9	2490.01
	25	625	30.3	918.09	55.3	3058.09	21.3	453.69	46.3	2143.69	51.6	2662.56
	25	625	29.2	852.64	54.2	2937.64	19.4	376.36	44.4	1971.36	48.6	2361.96
530	23	529	30.3	918.09	53.3	2840.89	17.9	320.41	40.9	1672.81	48.2	2323.24
	23	529	25.0	625.00	48.0	2304.00	19.6	384.16	42.6	1814.76	44.6	1989.16
	23	529	27.6	761.76	50.6	2560.36	20.3	412.09	43.3	1874.89	47.9	2294.41
	23	529	24.6	605.16	47.6	2265.76	18.9	357.21	41.9	1755.61	43.5	1892.25
	23	529	25.7	660.49	48.7	2371.69	17.5	306.25	40.5	1640.25	43.2	1866.24
	23	529	24.4	595.36	47.4	2246.76	17.6	309.76	40.6	1648.36	42.0	1764.00
	23	529	21.6	466.56	44.6	1989.16	16.7	278.89	39.7	1576.09	38.3	1466.89
	23	529	22.6	510.76	45.6	2079.36	19.3	372.49	42.3	1789.29	41.9	1755.61

Subject's number	Age (t)	t^2	R.T. to light (l)	l^2	t + l	$(t + l)^2$	R.T. to sound (s)	s^2	s + t	$(s + t)^2$	s + l	$(s + l)^2$
530	23	529	26.4	696.96	49.4	2440.36	17.6	309.76	40.6	1648.36	44.0	1936.00
447	26	676	35.0	1225.00	61.0	3721.00	20.6	424.36	46.6	2171.56	55.6	3091.36
	26	676	30.1	906.01	56.1	3147.21	21.0	441.00	47.0	2209.00	51.1	2611.21
	26	676	28.8	829.44	54.8	3003.04	20.6	424.36	46.6	2171.56	49.4	2440.36
	26	676	29.1	846.81	55.1	3036.01	18.4	338.56	44.4	1971.36	47.5	2256.25
	26	676	25.5	650.25	51.5	2652.25	17.8	316.84	43.8	1918.44	45.3	2052.09
	26	676	28.0	784.00	54.0	2916.00	16.4	268.96	42.4	1797.76	44.4	1971.36
	26	676	27.2	739.84	53.2	2830.24	16.4	268.96	42.4	1797.76	43.6	1900.96
	26	676	26.2	686.44	52.2	2724.84	16.2	262.44	42.2	1780.84	42.4	1797.76
	26	676	28.8	829.44	54.8	3003.04	18.4	338.56	44.2	1953.64	47.2	2227.84
675	25	625	30.7	942.49	55.7	3102.49	19.1	364.81	44.1	1944.81	49.8	2480.04
	25	625	27.6	761.76	52.6	2766.74	22.7	515.29	47.7	2275.29	50.3	2530.09
	25	625	24.5	600.25	49.5	2450.25	20.2	408.04	45.2	2043.04	44.7	1998.09
	25	625	27.3	745.29	52.3	2735.29	19.6	384.16	44.6	1989.16	46.9	2199.61
	25	625	24.2	585.64	49.2	2420.64	16.6	275.56	41.6	1730.56	40.8	1664.64
	25	625	28.7	823.69	53.7	2883.69	20.6	424.36	45.6	2079.36	49.3	2430.49
	25	625	24.8	615.04	49.8	2480.04	18.9	357.21	43.9	1927.21	43.7	1909.69

Subject's number	Age (t)	t^2	R.T. to light (l)	l^2	t + l	$(t + l)^2$	R.T. to sound (s)	s^2	s + t	$(s + t)^2$	s + l	$(s + l)^2$
675	25	625	26.8	718.24	51.8	2683.24	19.0	361.00	44.0	1936.00	45.8	2097.64
	25	625	21.6	466.56	46.6	2171.56	19.7	388.09	44.7	1998.09	41.3	1705.69
	25	625	25.0	625.00	50.0	2500.00	19.8	392.04	44.8	2007.04	44.8	2007.04
	25	625	22.0	484.00	47.0	2209.00	19.5	380.25	44.5	1980.25	41.5	1722.25
611	27	729	30.8	948.64	57.8	3340.84	14.1	198.81	41.1	1689.21	44.9	2016.01
	27	729	33.3	1108.89	60.3	3636.09	21.2	449.44	48.2	2323.24	54.3	2970.25
	27	729	30.9	954.81	57.9	3352.41	18.4	338.56	45.4	2061.16	49.3	2430.49
	27	729	27.4	750.76	54.4	2959.36	19.9	396.01	46.9	2199.61	47.3	2237.29
	27	729	23.1	533.61	50.1	2510.01	17.9	320.41	44.9	2016.01	41.0	1681.00
	27	729	25.5	650.25	52.5	2756.25	15.9	252.81	42.9	1840.41	41.4	1713.96
	27	729	21.8	475.24	48.6	2381.44	17.5	306.25	44.5	1980.25	39.3	1544.49
	27	729	25.2	635.04	52.2	2724.84	18.8	353.44	45.8	2097.64	44.0	1936.00
	27	729	25.9	670.81	52.9	2798.41	19.5	380.25	46.5	2162.25	45.4	2061.16
520	24	576	33.2	1102.24	57.2	3271.84	21.7	470.89	45.7	2088.49	53.9	2905.21
	24	576	29.9	894.01	53.9	2905.21	18.8	353.44	42.8	1831.84	48.7	2371.69
	24	576	30.3	918.09	54.3	2948.49	20.5	420.25	44.5	1980.25	50.8	2580.64

Subject's number	Age (t)	t^2	R.T. to light (l)	l^2	t + l	$(t + l)^2$	R.T. to sound (s)	s^2	s + t	$(s + t)^2$	s + l	$(s + l)^2$
520	24	576	24.5	600.25	48.5	2352.25	19.4	376.36	43.4	1883.56	43.9	1927.21
	24	576	26.2	686.44	50.2	2520.04	20.8	432.64	44.8	2007.04	47.0	2209.00
	24	576	26.9	723.61	50.9	2590.81	19.1	364.81	43.1	1857.61	46.0	2116.00
	24	576	24.1	580.81	48.1	2313.61	18.1	327.61	42.1	1772.41	42.2	1780.84
	24	576	30.5	930.25	54.5	2970.25	21.2	449.44	45.2	2043.04	51.7	2672.89
	24	576	29.2	852.64	53.2	2830.24	19.6	384.16	43.6	1900.96	48.8	2381.44
	24	576	31.0	961.00	55.0	3025.00	20.6	424.36	44.6	1989.16	51.6	2662.56
422	27	729	30.3	918.09	57.3	3283.29	18.9	357.21	45.9	2106.81	49.2	2420.64
	27	729	21.1	445.21	48.1	2313.61	16.8	282.24	43.8	1918.44	37.9	1436.41
	27	729	26.3	691.69	53.3	2840.89	18.0	324.00	45.0	2025.00	44.3	1962.49
	27	729	33.6	1128.96	60.6	3672.36	21.2	449.44	48.2	2323.24	54.8	3003.04
	27	729	24.9	620.01	51.9	2693.61	20.4	416.16	47.4	2246.76	45.3	2052.09
	27	729	25.6	655.36	52.6	2766.76	15.5	240.25	42.5	1806.25	41.1	1689.21
	27	729	31.9	1017.61	58.9	3469.21	18.8	353.44	45.8	2097.64	50.7	2570.49
	27	729	23.0	529.00	50.0	2500.00	15.2	231.04	42.2	1780.84	38.2	1459.24
	27	729	23.7	561.69	50.7	2570.49	16.4	268.96	43.4	1883.56	40.1	1608.01

Subject's number	Age (t)	t^2	R.T. to light (l)	l^2	t + l	$(t + l)^2$	R.T. to sound (s)	s^2	s + t	$(s + t)^2$	s + l	$(s + l)^2$
422	27	729	21.2	449.44	48.2	2323.24	16.2	262.44	43.2	1866.24	37.4	1398.76
191	23	529	26.1	681.21	49.1	2410.81	17.8	316.84	40.8	1664.64	43.9	1927.21
	23	529	24.2	585.64	47.2	2227.84	17.8	316.84	40.8	1664.64	42.0	1764.00
	23	529	23.3	542.89	46.3	2143.69	17.2	295.84	40.2	1616.04	40.5	1640.25
	23	529	19.9	396.01	42.9	1840.41	17.0	289.00	40.0	1600.00	36.9	1361.61
	23	529	21.9	479.61	44.9	2016.01	18.1	327.61	41.1	1689.21	40.0	1600.00
	23	529	21.3	453.69	44.3	1962.49	16.5	272.25	39.5	1560.25	37.8	1428.84
355	25	625	21.5	462.25	46.5	2162.25	14.8	219.04	39.8	1584.04	36.3	1317.69
	25	625	23.0	529.00	48.0	2304.00	15.1	228.01	40.1	1608.01	38.1	1451.61
	25	625	25.6	655.36	50.6	2560.36	17.3	299.29	42.3	1789.29	42.9	1840.41
	25	625	22.4	501.76	47.4	2246.76	15.4	237.16	40.4	1632.16	37.8	1428.84
	25	625	23.6	556.96	48.6	2361.96	19.0	361.00	44.0	1936.00	42.6	1814.76
	25	625	23.9	571.21	48.9	2391.21	19.9	396.01	44.9	2016.01	43.8	1918.44
	25	625	25.6	655.36	50.6	2560.36	20.1	404.01	45.1	2034.01	45.7	2088.49
	25	625	25.8	665.64	50.8	2580.64	17.8	316.84	42.8	1831.84	43.6	1900.96
	25	625	25.6	655.36	50.6	2560.36	18.1	327.61	43.1	1857.61	43.7	1909.69
	25	625	25.5	650.25	50.5	2550.25	16.9	285.61	41.9	1755.61	42.4	1797.76

Subject's number	Age (t)	t^2	R.T. to light (l)	l^2	t + l	$(t + l)^2$	R.T. to sound (s)	s^2	s + t	$(s + t)^2$	s + l	$(s + l)^2$
378	26	676	39.9	1592.01	65.9	4342.81	26.1	681.21	52.1	2714.41	66.0	4356.00
	26	676	31.0	961.00	57.0	3249.00	24.2	585.64	50.2	2520.04	55.2	3047.04
	26	676	29.8	888.04	55.8	3113.64	19.2	368.64	45.2	2043.04	49.0	2401.00
	26	676	28.2	795.24	54.2	2937.64	21.9	479.61	47.9	2294.41	50.1	2510.01
	26	676	29.1	846.81	55.1	3036.01	24.1	580.81	50.1	2510.01	55.2	3047.04
	26	676	27.1	734.41	53.1	2819.61	24.8	615.04	50.8	2580.64	51.9	2693.61
	26	676	27.2	739.84	53.2	2830.24	22.2	492.84	48.2	2323.24	49.4	2440.36
	26	676	30.3	918.09	56.3	3169.69	23.4	547.56	49.4	2440.36	53.7	2883.69
	26	676	30.8	948.64	56.8	3226.24	24.8	615.04	50.8	2580.64	55.6	3091.36
103	26	676	29.3	858.49	55.3	3058.09	19.8	392.04	45.8	2097.64	49.1	2410.81
	26	676	31.0	961.00	57.0	3249.00	20.2	408.04	46.2	2134.44	51.2	2621.44
	26	676	26.9	723.61	52.9	2798.41	21.2	449.44	47.2	2227.84	48.1	2313.61
	26	676	26.5	702.25	52.5	2756.25	18.8	353.44	44.8	2007.04	45.3	2052.09
	26	676	25.9	670.81	51.9	2693.61	16.3	265.69	42.3	1789.29	42.2	1780.84
	26	676	22.0	484.00	48.0	2304.00	17.0	289.00	43.0	1849.00	39.0	1521.00
	26	676	23.0	529.00	49.0	2401.00	18.6	345.96	44.6	1989.16	41.6	1730.56
	26	676	22.5	506.25	48.5	2352.25	19.5	380.25	45.5	2070.25	42.0	1764.00

Subject's number	Age (t)	t^2	R.T. to light (l)	l^2	t + l	$(t + l)^2$	R.T. to sound (s)	s^2	s + t	$(s + t)^2$	s + l	$(s + l)^2$
103	26	676	23.2	538.24	49.2	2420.64	16.4	268.96	42.4	1797.76	39.6	1568.16
	26	676	23.6	556.96	49.6	2460.16	16.6	275.56	42.6	1814.76	40.2	1616.04
	26	676	34.1	1162.81	60.1	3612.01	15.3	234.09	41.3	1705.69	49.4	2440.36
27	26	676	29.6	876.16	55.6	3091.36	15.2	231.04	41.2	1697.44	44.8	2007.04
	26	676	25.9	670.81	51.9	2693.61	17.5	306.25	43.5	1892.25	43.4	1883.56
	26	676	29.3	858.49	55.3	3058.09	17.9	320.41	43.9	1927.21	47.2	2227.84
	26	676	25.2	635.04	51.2	2621.44	18.5	342.25	44.5	1980.25	43.7	1909.69
	26	676	34.2	1169.64	60.2	3624.04	18.7	349.69	44.7	1998.09	52.9	2798.41
	26	676	29.6	876.16	55.6	3091.36	17.7	313.29	43.7	1909.69	47.3	2237.29
	26	676	30.5	930.25	56.5	3192.25	19.2	368.64	45.2	2043.04	49.7	2470.09
	26	676	29.8	888.04	55.8	3113.64	17.6	309.76	43.6	1900.96	47.4	2246.76
	26	676	32.0	1024.00	58.0	3364.00	16.8	282.24	42.8	1831.84	48.8	2381.44
	26	676	33.0	1089.00	59.0	3481.00	18.8	353.44	44.8	2007.04	51.8	2683.24
	26	676	36.3	1317.69	62.3	3881.29	18.6	345.96	44.6	1989.16	54.9	3014.01
243	27	729	28.2	795.24	55.2	3047.04	16.8	282.24	43.8	1918.44	45.0	2025.00
	27	729	29.3	858.49	56.3	3169.69	15.2	231.04	42.9	1840.41	44.5	1980.25

Subject's number	Age (t)	t^2	R.T. to light (l)	l^2	t + l	$(t + l)^2$	R.T. to sound (s)	s^2	s + t	$(s + t)^2$	s + l	$(s + l)^2$
243	27	729	28.0	784.00	55.0	3025.00	15.2	231.04	42.9	1840.41	43.2	1866.24
	27	729	23.9	571.21	50.9	2590.81	15.0	225.00	42.0	1764.00	38.9	1513.21
	27	729	22.2	492.84	49.2	2420.64	14.8	219.04	41.8	1747.24	37.0	1369.00
	27	729	24.2	585.64	51.2	2621.44	14.5	210.25	41.5	1722.25	38.7	1497.69
	27	729	22.2	492.84	49.2	2420.64	15.0	225.00	42.0	1764.00	37.2	1383.84
	27	729	22.5	506.25	49.5	2450.25	14.7	216.09	41.7	1738.89	37.2	1383.84
	27	729	29.7	882.09	56.7	3214.89	13.3	176.89	40.3	1624.09	43.0	1849.00
	27	729	26.1	681.21	53.1	2819.61	12.2	148.84	39.2	1536.64	38.3	1466.89
	27	729	27.7	767.29	54.7	2992.09	12.4	153.76	39.4	1552.36	40.1	1608.01
	27	729	29.8	888.04	56.8	3226.24	12.1	146.41	39.1	1528.81	41.9	1755.61
209	24	576	29.4	864.36	53.4	2851.56	19.4	376.36	43.4	1883.56	48.8	2381.44
	24	576	24.8	615.04	48.8	2381.44	18.8	353.44	42.8	1831.84	43.6	1900.96
	24	576	26.6	707.25	50.6	2560.36	17.7	313.29	41.7	1738.89	44.3	1962.49
	24	576	28.5	812.25	52.5	2756.25	19.4	376.36	43.4	1883.56	47.9	2294.41
	24	576	27.6	761.76	51.6	2662.56	19.6	384.16	43.6	1900.96	47.2	2227.84
	24	576	27.0	729.00	51.0	2601.00	20.8	432.64	44.8	2007.04	47.8	2284.84
	24	576	31.6	998.56	55.6	3091.36	18.1	327.61	42.1	1772.41	49.7	2470.09

Subject's number	Age (t)	t^2	R.T. to light (l)	l^2	t + l	$(t + l)^2$	R.T. to sound (s)	s^2	s + t	$(s + t)^2$	s + l	$(s + l)^2$
209	24	576	34.0	1156.00	58.0	3364.00	19.5	380.25	43.5	1892.25	53.5	2862.25
	24	576	25.1	630.01	49.1	2410.81	19.2	368.64	43.2	1866.24	44.3	1962.49
	24	576	28.2	795.24	52.2	2724.84	19.6	384.16	43.6	1900.96	47.8	2284.84
529	25	625	27.4	750.76	52.4	2745.76	18.5	342.25	43.5	1892.25	45.9	2106.81
	25	625	25.8	665.64	50.8	2580.64	14.3	204.49	39.3	1544.49	40.1	1608.01
	25	625	20.5	420.25	45.5	2070.25	14.5	210.25	39.5	1560.25	35.0	1225.00
	25	625	21.0	441.00	46.0	2116.00	15.0	225.00	40.0	1600.00	36.0	1296.00
	25	625	21.9	479.61	46.9	2199.61	15.8	249.64	40.8	1664.64	37.7	1421.29
	25	625	20.4	416.16	45.4	2061.16	14.6	213.16	39.6	1568.16	35.0	1225.00
	25	625	21.7	470.89	46.7	2180.89	14.4	207.36	39.4	1552.36	36.1	1303.21
	25	625	20.4	416.16	45.4	2061.16	14.7	216.09	39.7	1576.09	35.1	1232.01
	25	625	19.6	384.16	44.6	1989.16	13.9	193.21	38.9	1513.21	33.5	1122.25
	25	625	19.9	396.01	44.9	2016.01	13.6	184.96	38.6	1489.96	33.5	1122.25
	25	625	19.0	361.00	44.0	1936.00	14.0	196.00	39.0	1521.00	33.0	1189.00
74	24	576	25.3	640.09	49.3	2430.49	17.6	309.76	41.6	1730.56	42.9	1840.41
	24	576	26.0	676.00	50.0	2500.00	17.5	306.25	41.5	1722.25	43.5	1892.25
	24	576	22.6	510.76	46.6	2171.56	16.1	259.21	40.1	1608.01	38.7	1497.69

Subject's number	Age (t)	t^2	R.T. to light (l)	l^2	t + l	$(t + l)^2$	R.T. to sound (s)	s^2	s + t	$(s + t)^2$	s + l	$(s + l)^2$
71	24	576	26.1	681.21	50.1	2510.01	19.3	372.49	43.3	1874.89	45.4	2061.16
	24	576	24.7	610.09	48.7	2371.69	17.1	292.41	41.1	1689.21	41.8	1747.24
	24	576	24.7	610.09	48.7	2371.69	17.2	295.84	41.2	1697.44	41.9	1755.61
	24	576	22.6	510.76	46.6	2171.56	18.5	342.25	42.5	1806.25	41.1	1689.21
	24	576	29.6	876.16	53.6	2872.96	19.3	372.49	43.3	1874.89	48.9	2391.21
	24	576	33.7	1135.69	57.7	3329.29	17.0	289.00	41.0	1681.00	50.7	2570.49
	24	576	32.2	1036.84	56.2	3158.44	18.3	334.89	42.3	1789.29	50.5	2550.25
	24	576	32.0	1024.00	56.0	3136.00	17.9	320.41	41.9	1755.61	49.9	2490.01
524	24	576	38.2	1459.24	64.2	4121.64	15.7	246.49	39.7	1576.09	53.9	2905.21
	24	576	37.1	1376.41	61.1	3733.21	12.6	158.76	36.6	1339.56	49.7	2470.09
	24	576	35.2	1239.04	59.2	3504.64	16.0	256.00	40.0	1600.00	51.2	2621.44
	24	576	32.3	1043.29	56.3	3169.69	14.4	207.36	38.4	1474.56	46.7	2180.89
	24	576	31.6	998.56	55.6	3091.36	15.6	243.36	39.6	1568.16	47.2	2227.84
	24	576	30.9	954.81	54.9	3014.01	14.7	216.09	38.7	1497.69	45.6	2079.36
	24	576	32.5	1056.25	56.5	3192.25	14.8	219.04	38.8	1505.44	47.3	2237.29
	24	576	30.2	912:04	54.2	2937.64	12.6	158.76	36.6	1339.56	42.8	1831.84
	24	576	34.5	1190.25	58.5	3422.25	19.2	368.64	43.2	1866.24	53.7	2883.69

Subject's number	Age (t)	t^2	R.T. to light (l)	l^2	t + l	$(t + l)^2$	R.T. to sound (s)	s^2	s + t	$(s + t)^2$	s + l	$(s + l)^2$
524	24	576	34.6	1197.16	58.6	3433.96	16.4	268.96	40.4	1632.16	51.0	2601.00
	24	576	33.7	1135.69	57.7	3329.29	17.8	316.84	41.8	1747.24	51.5	2652.25
8	28	784	30.8	948.64	58.8	3457.44	13.3	176.89	41.3	1705.69	44.1	1944.81
678	24	576	32.2	1036.84	56.2	3158.44	18.0	324.00	42.0	1764.00	50.2	2520.04
572	26	676	35.3	1246.09	61.3	3757.69	17.4	302.76	43.4	1883.56	52.7	2777.29
683	24	576	31.4	985.96	55.4	3069.16	22.6	510.76	46.6	2171.56	54.0	2916.00
239	29	841	33.2	1102.24	62.2	3868.84	24.9	620.01	53.9	2905.21	58.1	3375.61
250	23	529	33.1	1095.61	56.1	3147.21	14.8	219.04	37.8	1428.84	47.9	2294.41
359	27	729	29.7	882.09	56.7	3214.89	16.3	265.69	43.3	1874.89	46.0	2116.00
526	24	576	32.5	1056.25	56.5	3192.25	20.4	416.16	44.4	1971.36	52.9	2798.41
24	23	529	37.4	1398.76	60.4	3648.16	18.8	353.44	41.8	1747.24	56.2	3158.44
342	27	729	34.7	1204.09	61.7	3806.89	19.4	376.36	46.4	2152.96	54.1	2926.81
156	23	529	28.2	795.24	51.2	2621.44	17.6	309.76	40.6	1648.36	45.8	2097.64
130	26	676	29.5	870.25	55.5	3080.25	14.8	219.04	40.8	1664.64	44.3	1962.49
527	25	625	33.3	1108.89	58.3	3398.89	20.5	420.25	45.5	2070.25	53.8	2894.44
556	25	625	26.1	681.21	51.1	2611.21	19.1	364.81	44.1	1944.81	45.2	2043.04
54	26	676	29.7	882.09	55.7	3102.49	21.0	441.00	47.0	2209.00	50.7	2570.49

Subject's number	Age (t)	t^2	R.T. to light (l)	l^2	t + l	$(t + l)^2$	R.T. to sound (s)	s^2	s + t	$(s + t)^2$	s + l	$(s + l)^2$
310	23	529	32.2	1036.84	55.2	3047.04	18.1	327.61	41.1	1689.21	50.3	2530.09
146	22	484	33.0	1089.00	55.0	3025.00	18.4	338.56	40.4	1632.16	53.4	2851.56
268	23	529	25.8	665.64	48.8	2381.44	19.8	392.04	42.8	1831.84	45.6	2079.36
213	29	841	33.6	1128.96	62.6	3918.76	28.3	800.89	57.3	3283.29	61.9	3831.61
483	30	900	28.2	795.24	58.2	3387.24	18.0	324.00	48.0	2304.00	46.2	2134.44
681	25	625	32.8	1075.84	57.8	3340.84	20.7	428.49	45.7	2088.49	53.5	2862.25
374	24	576	27.4	750.76	51.4	2641.96	17.6	309.76	41.6	1730.56	45.0	2025.00
557	26	676	23.2	538.24	49.2	2420.64	17.0	289.00	43.0	1849.00	40.2	1616.04
543	26	676	33.9	1149.21	59.9	3588.01	23.8	566.44	49.8	2480.04	57.7	3329.29
552	33	1089	23.6	556.96	56.6	3203.56	17.0	289.00	50.0	2500.00	40.6	1648.36
	33	1089	25.6	655.36	58.6	3433.96	16.5	272.25	49.5	2450.25	42.1	1772.41
	33	1089	22.4	501.76	55.4	3069.16	16.8	282.24	49.8	2480.04	39.2	1536.64
	33	1089	23.4	547.56	56.4	3180.96	16.2	262.44	49.2	2420.64	39.6	1568.16
	33	1089	25.0	625.00	58.0	3364.00	16.4	268.96	49.4	2440.36	41.4	1713.96
	33	1089	24.0	576.00	57.0	3249.00	15.4	237.16	48.4	2342.56	39.4	1552.36
	33	1089	23.2	538.24	56.2	3158.44	17.6	309.76	50.6	2560.36	40.8	1664.64
	33	1089	23.6	556.96	56.6	3203.56	16.2	262.44	49.2	2420.64	39.8	1584.04

Subject's number	Age (t)	t^2	R.T. to light (l)	l^2	t + l	$(t + l)^2$	R.T. to sound (s)	s^2	s + t	$(s + t)^2$	s + l	$(s + l)^2$
552	33	1089	24.0	576.00	57.0	3249.00	17.4	302.76	50.4	2540.16	41.4	1713.96
	33	1089	23.6	556.96	56.6	3203.56	17.0	289.00	50.0	2500.00	40.6	1648.36
426	33	1089	34.6	1197.16	67.6	4569.76	16.2	262.44	49.2	2420.64	50.8	2580.64
	33	1089	33.2	1102.24	66.2	4382.44	18.7	349.69	51.7	2672.89	51.9	2693.61
	33	1089	28.8	829.44	61.8	3819.24	17.4	302.76	50.4	2540.16	46.2	2134.44
	33	1089	28.1	789.61	61.1	3733.21	16.0	256.00	49.0	2401.00	44.1	1944.81
	33	1089	29.1	846.81	62.1	3856.41	16.6	275.56	49.6	2460.16	45.7	2088.49
	33	1089	24.5	600.25	57.5	3306.25	15.4	237.16	48.4	2342.56	39.9	1592.01
	33	1089	24.4	595.36	57.4	3294.76	18.2	331.24	51.2	2621.44	42.6	1814.76
	33	1089	23.5	552.25	56.5	3192.25	16.2	262.44	49.2	2420.64	39.7	1576.09
	33	1089	24.0	576.00	57.0	3249.00	15.6	243.36	48.6	2361.96	39.6	1568.16
	33	1089	21.4	457.96	54.4	2959.36	15.3	234.09	48.3	2332.89	36.7	1346.89
360	36	1296	29.5	870.25	65.5	4290.25	20.0	400.00	56.0	3136.00	49.5	2450.25
	36	1296	29.1	846.81	65.1	4238.01	18.4	338.56	54.4	2959.36	47.5	2256.25
	36	1296	27.9	778.41	63.1	3981.61	20.0	400.00	56.0	3136.00	47.9	2294.41
	36	1296	28.3	800.89	62.3	3881.29	18.5	342.25	54.5	2970.25	46.8	2190.24
	36	1296	31.9	1017.61	67.9	4610.41	20.8	432.64	56.8	3226.24	52.7	2777.29

Subject's number	Age (t)	t^2	R.T. to light (l)	l^2	t + l	$(t + l)^2$	R.T. to sound (s)	s^2	s + t	$(s + t)^2$	s + l	$(s + l)^2$
360	36	1296	30.8	948.64	66.8	4462.24	20.7	428.49	56.7	3214.89	51.5	2652.25
	36	1296	29.0	841.00	65.0	4225.00	21.3	453.69	57.3	3283.29	50.3	2530.09
	36	1296	30.2	912.04	66.2	4382.44	21.8	475.24	57.8	3340.84	52.0	2704.00
	36	1296	33.1	1095.61	69.1	4774.81	25.0	625.00	61.0	3721.00	58.1	3375.61
	36	1296	34.0	1156.00	70.0	4900.00	20.6	424.36	56.6	3203.56	54.6	2981.16
660	30	900	26.6	707.56	56.6	3203.56	16.2	262.44	46.2	2134.44	42.8	1831.84
	30	900	25.4	645.16	55.4	3069.16	14.8	219.04	44.2	1953.64	40.2	1616.04
	30	900	25.3	640.09	55.3	3058.09	18.2	331.24	48.2	2323.24	43.5	1892.25
	30	900	24.8	615.04	54.8	3003.04	16.1	259.21	46.1	2125.21	40.9	1672.81
	30	900	21.8	475.24	51.8	2683.24	15.7	246.49	45.7	2088.49	37.5	1406.25
	30	900	27.8	772.84	57.8	3340.84	20.0	400.00	50.0	2500.00	47.8	2284.84
	30	900	24.8	615.04	54.8	3003.04	18.3	334.89	48.3	2332.89	43.1	1857.61
	30	900	21.8	475.24	51.8	2683.24	16.9	285.61	46.9	2199.61	38.7	1497.69
	30	900	22.1	488.41	52.1	2714.41	15.9	252.81	45.9	2106.81	38.0	1444.00
	30	900	22.7	515.29	52.7	2777.29	16.6	275.56	46.6	2171.56	39.3	1544.49
607	34	1156	31.0	961.00	65.0	4225.00	19.0	361.00	53.0	2809.00	50.0	2500.00
	34	1156	28.3	800.89	62.3	3881.29	16.9	285.61	50.9	2590.81	45.2	2043.04

Subject's number	Age (t)	t^2	R.T. to light (l)	l^2	t + l	$(t + l)^2$	R.T. to sound (s)	s^2	s + t	$(s + t)^2$	s + l	$(s + l)^2$
607	34	1156	29.1	846.81	63.1	3981.61	19.6	384.16	53.6	2872.96	48.7	2371.69
	34	1156	30.1	906.01	64.1	4108.81	24.9	620.01	58.9	3469.21	55.0	3025.00
	34	1156	27.2	739.84	61.2	3745.44	17.9	320.41	51.9	2693.61	45.1	2034.01
	34	1156	27.4	750.76	61.4	3769.96	18.1	327.61	52.1	2714.41	45.5	2070.25
	34	1156	28.0	784.00	62.0	3844.00	23.9	571.21	57.9	3352.41	51.9	2693.61
	34	1156	27.2	739.84	61.2	3745.44	18.3	334.89	52.3	2735.29	45.5	2070.25
1001	17	289	28.3	800.89	45.3	2052.09	16.3	265.69	33.3	1108.89	44.6	1989.16
	17	289	23.4	547.56	40.4	1632.16	15.2	231.04	32.2	1036.84	38.6	1489.96
	17	289	24.8	615.04	41.8	1747.24	16.8	282.24	33.8	1142.44	41.6	1730.56
	17	289	24.0	576.00	41.0	1681.00	17.2	295.84	34.2	1169.64	41.2	1697.44
	17	289	23.7	561.69	40.7	1656.49	14.9	222.01	31.9	1017.61	38.6	1489.96
	17	289	24.6	605.16	41.6	1730.56	14.9	222.01	31.9	1017.61	39.5	1560.25
	17	289	24.7	610.09	41.7	1738.89	16.8	282.24	33.8	1142.44	41.5	1722.25
	17	289	23.0	529.00	40.0	1600.00	15.5	240.25	32.5	1056.25	38.5	1482.25
1002	17	289	34.7	1204.09	51.7	2672.89	22.2	492.84	39.2	1536.64	56.9	3237.61
	17	289	37.7	1421.29	54.7	2992.09	30.4	924.16	47.4	2246.76	68.1	4637.61

Subject's number	Age (t)	t^2	R.T. to light (l)	l^2	t + l	$(t + l)^2$	R.T. to sound (s)	s^2	s + t	$(s + t)^2$	s + l	$(s + l)^2$
1002	17	289	31.8	1011.24	48.8	2381.44	25.8	665.64	42.8	1831.84	57.6	3317.76
	17	289	34.5	1190.25	51.5	2652.25	21.6	466.56	48.6	2361.96	56.1	3147.21
	17	289	32.1	1030.41	49.1	2410.81	20.6	424.36	37.6	1413.76	52.7	2777.29
	17	289	28.6	817.96	45.6	2079.36	19.4	376.36	36.4	1324.96	48.0	2304.00
	17	289	30.6	936.36	47.6	2265.76	20.2	408.04	37.2	1383.84	50.8	2580.64
	17	289	27.2	739.84	44.2	1953.64	20.6	424.36	37.6	1413.76	47.8	2284.84
547	30	900	27.7	767.29	57.7	3329.29	18.4	338.56	48.4	2342.56	46.1	2125.21
	30	900	27.0	729.00	57.0	3249.00	20.5	420.25	50.5	2550.25	47.5	2256.25
	30	900	27.9	778.41	57.9	3352.41	21.6	466.56	51.6	2662.56	49.5	2450.25
	30	900	30.8	948.64	60.8	3696.64	20.7	428.49	50.7	2570.49	51.5	2652.25
	30	900	32.9	1082.41	62.9	3956.41	24.0	576.00	54.0	2916.00	56.9	3237.61
	30	900	29.6	876.16	59.6	3552.16	20.0	400.00	50.0	2500.00	49.6	2460.16
	30	900	29.6	876.16	59.6	3552.16	20.2	408.04	50.2	2520.04	49.8	2480.04
	30	900	30.3	918.09	60.3	3636.09	21.6	466.56	51.6	2662.56	51.9	2693.61
500	37	1369	34.0	1156.00	71.0	5041.00	19.9	396.01	56.9	3237.61	53.9	2905.21
	37	1369	34.2	1169.64	71.2	5069.44	19.2	368.64	56.2	3158.44	53.4	2851.56
	37	1369	29.8	888.04	66.8	4462.24	17.5	306.25	54.5	2970.25	47.3	2237.29

Subject's number	Age (t)	t^2	R.T. to light (l)	l^2	t + l	$(t + l)^2$	R.T. to sound (s)	s^2	s + t	$(s + t)^2$	s + l	$(s + l)^2$
500	37	1369	32.2	1036.84	69.2	4788.64	17.4	302.76	54.4	2959.36	49.6	2460.16
	37	1369	30.2	912.04	67.2	4515.84	18.9	357.21	55.9	3124.81	49.1	2410.81
	37	1369	29.7	882.09	66.7	4448.89	21.2	449.44	58.2	3387.24	50.9	2590.81
	37	1369	29.9	894.01	66.9	4475.61	18.8	353.44	55.8	3113.64	48.7	2371.69
	37	1369	29.0	841.00	66.0	4356.00	19.6	384.16	56.6	3203.56	48.6	2361.96
	37	1369	26.7	712.89	63.7	4057.69	20.4	416.16	57.4	3294.76	47.1	2218.41
	37	1369	30.5	930.25	67.5	4556.25	26.3	691.69	63.3	4006.89	56.8	3226.24
186	26	676	27.4	750.76	53.4	2851.56	20.6	424.36	46.6	2171.56	48.0	2304.00
	26	676	30.1	906.01	56.1	3147.21	19.6	384.16	45.6	2079.36	49.7	2470.09
	26	676	27.4	750.76	53.4	2851.56	19.0	361.00	45.0	2025.00	46.4	2152.96
	26	676	29.6	876.16	55.6	3091.36	25.6	655.36	51.6	2662.56	55.2	3047.04
	26	676	28.7	823.69	54.7	2992.09	22.9	524.41	48.9	2391.21	51.6	2662.56
	26	676	27.3	745.29	53.3	2840.89	21.8	475.24	47.9	2294.41	49.1	2410.81
	26	676	25.2	635.04	51.2	2621.44	17.8	316.84	43.8	1918.44	43.0	1849.00
	26	676	25.2	635.04	51.2	2621.44	19.5	380.25	45.5	2070.25	44.7	1998.09
	26	676	25.0	625.00	51.0	2601.00	19.7	388.09	45.7	2088.49	44.7	1998.09
	26	676	28.7	823.69	54.7	2992.09	23.0	529.00	49.0	2401.00	51.7	2672.89

Subject's number	Age (t)	t^2	R.T. to light (l)	l^2	t + l	$(t + l)^2$	R.T. to sound (s)	s^2	s + t	$(s + t)^2$	s + l	$(s + l)^2$
667	26	676	29.8	888.04	55.8	3113.64	16.5	272.25	42.5	1806.25	46.3	2143.69
	26	676	28.7	823.69	54.7	2992.09	15.4	237.16	41.4	1713.96	44.1	1944.81
	26	676	31.7	1004.89	57.7	3329.29	16.9	285.61	42.9	1840.41	48.6	2361.96
	26	676	30.4	924.16	56.4	3180.96	14.8	219.04	40.8	1664.64	45.2	2043.04
	26	676	30.0	900.00	56.0	3136.00	16.5	272.25	42.5	1806.25	46.5	2162.25
	26	676	28.7	823.69	54.7	2992.09	14.5	210.25	40.5	1640.25	43.2	1866.24
	26	676	29.9	894.01	55.9	3124.81	15.7	246.49	41.7	1738.89	45.6	2079.36
	26	676	29.3	858.49	55.3	3058.09	14.7	216.09	40.7	1656.49	44.0	1936.00
	26	676	29.0	841.00	55.0	3025.00	14.6	213.16	40.6	1648.36	43.6	1900.96
	26	676	28.4	806.56	54.4	2959.36	15.0	225.00	41.0	1681.00	43.4	1883.56
19	29	841	30.0	900.00	59.0	3481.00	25.2	635.04	54.2	2937.64	55.2	3047.04
	29	841	30.5	930.25	59.5	3540.25	22.7	515.29	51.7	2672.89	53.2	2830.24
	29	841	29.9	894.01	58.9	3469.21	20.9	436.81	49.9	2490.01	50.8	2580.64
	29	841	33.1	1095.61	62.1	3856.41	27.0	729.00	56.0	3136.00	60.1	3612.01
	29	841	29.7	882.09	58.7	3445.69	22.4	501.76	51.4	2641.96	52.1	2714.41
	29	841	33.4	1115.56	62.4	3893.76	24.6	605.16	53.6	2872.96	58.0	3364.00
	29	841	33.0	1089.00	62.0	3844.00	25.3	640.09	54.3	2948.49	58.3	3398.89

Subject's number	Age (t)	t^2	R.T. to light (l)	l^2	t + l	$(t + l)^2$	R.T. to sound (s)	s^2	s + t	$(s + t)^2$	s + l	$(s + l)^2$
19	29	841	35.8	1281.64	64.8	4199.04	25.2	635.04	54.2	2937.64	61.0	3721.00
69	30	900	34.5	1190.25	64.5	4160.25	19.8	392.04	49.8	2480.04	54.3	2948.49
	30	900	35.5	1260.25	65.5	4290.25	20.0	400.00	50.0	2500.00	55.5	3080.25
	30	900	33.2	1102.24	63.2	3994.24	20.8	432.64	50.8	2580.64	54.0	2916.00
	30	900	34.6	1197.16	64.6	4173.16	19.9	396.01	49.9	2490.01	54.5	2970.25
	30	900	35.2	1239.04	65.2	4251.04	21.3	453.69	51.3	2631.69	56.5	3192.25
	30	900	35.5	1260.25	65.5	4290.25	19.7	388.09	49.7	2470.09	55.2	3047.04
	30	900	34.9	1218.01	64.9	4212.01	21.6	466.56	51.6	2662.56	56.5	3192.25
	30	900	36.7	1346.89	66.7	4448.89	20.8	432.64	50.8	2580.64	57.5	3306.25
	30	900	34.0	1156.00	64.0	4096.00	20.9	436.81	50.9	2590.81	54.9	3014.01
	30	900	36.1	1303.21	66.1	4369.21	22.4	501.76	52.4	2745.76	58.5	3422.25
308	36	1296	39.3	1544.49	75.3	5670.09	21.4	457.96	57.4	3294.76	60.7	3684.49
	36	1296	36.1	1303.21	72.1	5198.41	19.2	368.64	55.2	3047.04	55.3	3058.09
	36	1296	33.0	1089.00	69.0	4761.00	19.4	376.36	55.4	3069.16	52.4	2745.76
	36	1296	36.5	1332.25	72.5	5256.25	20.1	404.01	56.1	3147.21	56.6	3203.56
	36	1296	33.9	1149.21	69.9	4886.01	19.1	364.81	55.1	3036.01	53.0	2809.00
	36	1296	37.0	1369.00	73.0	5329.00	19.2	368.64	55.2	3047.04	56.2	3158.44

Subject's number	Age (t)	t^2	R.T. to light (l)	l^2	t + l	$(t + l)^2$	R.T. to sound (s)	s^2	s + t	$(s + t)^2$	s + l	$(s + l)^2$
308	36	1296	34.7	1204.09	70.7	4998.49	18.9	357.21	54.9	3014.01	53.6	2872.96
	36	1296	37.8	1428.84	73.8	5446.44	20.4	416.16	56.4	3180.96	58.2	3387.24
	36	1296	38.9	1513.21	74.9	5610.01	21.8	475.24	57.8	3340.84	60.7	3684.49
	36	1296	39.3	1544.49	75.3	5670.09	23.6	556.96	59.6	3552.16	62.9	3956.41
1003	23	529	33.5	1122.25	56.5	3192.25	17.9	320.41	40.9	1672.81	51.4	2641.96
1004	33	1089	33.9	1149.21	66.9	4475.61	17.1	292.41	50.1	2510.01	51.0	2601.00
1005	35	1225	31.7	1004.89	66.7	4448.89	18.1	327.61	53.1	2819.61	49.8	2480.04
117	24	576	34.0	1156.00	58.0	3364.00	21.6	466.56	45.6	2079.36	55.6	3091.36
604	24	576	26.5	702.25	50.5	2550.25	19.2	368.64	43.2	1866.24	45.7	2088.49
418	25	625	32.2	1036.84	57.2	3271.84	18.2	331.24	43.2	1866.24	50.4	2540.16
202	26	676	33.0	1089.00	59.0	3481.00	18.2	331.24	44.2	1953.64	51.2	2621.44
262	27	729	32.9	1082.41	59.9	3588.01	20.0	400.00	47.0	2209.00	52.9	2798.41
539	25	625	30.4	924.16	55.4	3069.16	19.0	361.00	44.0	1936.00	49.4	2440.36
608	30	900	28.0	784.00	58.0	3364.00	15.0	225.00	45.0	2025.00	43.0	1849.00
528	22	484	31.4	985.96	53.4	2851.56	18.4	338.56	40.4	1632.16	49.8	2480.04
216	26	676	30.4	924.16	56.4	3180.96	18.2	331.24	44.2	1953.64	48.6	2361.96
212	36	1296	33.7	1135.69	69.7	4858.09	22.3	497.29	58.3	3398.89	56.0	3136.00

Subject's number	Age (t)	t^2	R.T. to light (l)	l^2	t + l	$(t + l)^2$	R.T. to sound (s)	s^2	s + t	$(s + t)^2$	s + l	$(s + l)^2$
212	36	1296	31.1	967.21	67.1	4502.41	21.5	462.25	57.5	3306.25	52.6	2766.76
	36	1296	29.0	841.00	65.0	4225.00	20.0	400.00	56.0	3136.00	49.0	2401.00
	36	1296	31.9	1017.61	67.9	4610.41	22.9	524.41	58.9	3469.21	54.8	3003.04
	36	1296	28.9	835.21	64.9	4212.01	20.2	408.04	56.2	3158.44	49.1	2410.81
	36	1296	32.4	1049.76	68.4	4678.56	21.2	449.44	57.2	3271.84	53.6	2872.96
591	36	1296	42.3	1789.29	78.3	6130.89	25.8	665.64	61.8	3819.24	68.1	4637.61
	36	1296	32.1	1030.41	68.1	4637.61	23.0	529.00	59.0	3481.00	55.1	3036.01
	36	1296	33.0	1089.00	69.0	4761.00	23.3	542.89	59.3	3516.49	56.3	3169.69
	36	1296	27.7	767.29	63.7	4057.69	20.2	408.04	56.2	3158.44	47.9	2294.41
	36	1296	24.0	576.00	60.0	3600.00	17.5	306.25	53.5	2862.25	41.5	1722.25
	36	1296	25.6	655.36	61.6	3794.56	15.8	249.64	51.8	2683.24	41.4	1713.96
623	33	1089	32.1	1030.41	65.1	4238.01	21.5	462.25	54.5	2970.25	53.6	2872.96
	33	1089	39.9	1592.01	72.9	5314.41	23.3	542.89	56.3	3169.69	63.2	3994.24
	33	1089	35.2	1239.04	68.2	4651.24	23.7	561.69	56.7	3214.89	58.9	3469.21
	33	1089	35.6	1267.36	68.6	4705.96	21.7	470.89	54.7	2992.09	57.3	3283.29
	33	1089	31.0	961.00	64.0	4096.00	23.3	542.89	56.3	3169.69	54.3	2948.49
	33	1089	31.7	1004.89	64.7	4186.09	19.4	376.36	52.4	2745.76	51.1	2611.21

Subject's number	Age (t)	t^2	R.T. to light (l)	l^2	t + l	$(t + l)^2$	R.T. to sound (s)	s^2	s + t	$(s + t)^2$	s + l	$(s + l)^2$
368	29	841	22.9	524.41	51.9	2693.61	17.0	289.00	46.0	2116.00	39.9	1592.01
107	23	529	30.8	948.64	53.8	2894.44	23.2	538.24	46.2	2134.44	54.0	2916.00
682	28	784	24.7	610.09	52.7	2777.29	17.4	302.76	45.4	2061.16	42.1	1772.41
162	23	529	25.1	630.01	48.1	2313.61	18.0	324.00	41.0	1681.00	43.1	1857.61
<u>TOTAL</u> 407	11101	311325	11656.0	340150.41	22756.5	1291220.50	7655.5	147372.96	18767.8	878465.82	19316.4	935156.97
<u>MEAN</u>	27.28	764.92	28.64	835.75	55.9	3172.53	18.8	362.09	46.1	2158.39	47.5	2290.31
					Normal readings of men of both age groups.							
<u>MEAN</u> 509	30.46	988.09	28.86	850.96	59.31	3612.58	19.19	381.44	49.65	2557.88		

T A B L E xviA.

NORMAL READINGS FROM 2 MEN BETWEEN THE AGES OF 37 and 53 YEARS, AND THE MEAN VALUES FOR ALL THE NORMAL READINGS IN THIS AGE GROUP.

Table xviA Normal Readings of Men Between 37 and 53.

Subject's number	Age (t)	t^2	R.T. to light (l)	l^2	t + l	$(t + l)^2$	R.T. to sound (s)	s^2	s + t	$(s + t)^2$
1007	42	1764	32.6	1062.76	74.6	5565.16	16.8	282.24	58.8	3457.44
	42	1764	32.3	1043.29	74.3	5520.49	16.2	262.44	58.2	3387.24
	42	1764	27.9	778.41	69.9	4886.01	15.9	252.81	57.9	3352.41
	42	1764	31.5	992.25	73.5	5402.25	16.0	256.00	58.0	3364.00
	42	1764	31.7	1004.89	73.7	5431.69	15.7	246.49	57.7	3329.29
	42	1764	30.7	942.49	72.7	5285.29	16.2	262.44	58.2	3387.24
	42	1764	29.7	882.09	71.7	5140.89	16.4	268.96	58.4	3410.56
	42	1764	27.9	778.41	69.9	4886.01	16.1	259.21	58.1	3375.61
	42	1764	31.5	992.25	73.5	5402.25	20.2	408.04	62.2	3868.84
	42	1764	29.5	870.25	71.5	5112.25	19.4	376.36	61.4	3769.96
429	38	1444	28.1	789.61	66.1	4369.21	18.1	327.61	56.1	3147.21
	38	1444	27.8	772.84	65.8	4329.64	16.8	282.24	54.8	3003.04
	38	1444	25.2	635.04	63.2	3994.24	15.9	252.81	53.9	2905.21
	38	1444	25.1	630.01	63.1	3981.61	14.4	207.36	52.4	2745.76
	38	1444	23.0	529.00	61.0	3721.00	15.5	240.25	53.5	2862.25
	38	1444	27.1	734.41	65.1	4238.01	15.7	246.49	53.7	2883.69
	38	1444	26.3	691.69	64.3	4134.49	15.9	252.81	53.9	2905.21

Subject's number	Age (t)	t^2	R.T. to light (l)	l^2	t + l	$(t + l)^2$	R.T. to sound (s)	s^2	s + t	$(s + t)^2$
429	38	1444	26.5	702.25	64.5	4160.25	18.7	349.69	56.7	3214.89
<u>TOTAL</u> 18	724	29192	514.4	14831.94	1238.4	85560.74	299.9	5034.25	1023.9	58369.85
<u>MEAN</u>	40.22	1621.7	28.58	824.0	68.8	4753.37	16.66	279.68	56.88	3242.77
<u>Totals of both Tables</u> 102	4402	191614	3031.8	92986.02	7433.8	547584.82	2110.7	46780.95	6512.7	423493.55
<u>Averages of both Tables combined</u>	43.16	1878.57	29.72	911.63	72.88	5368.48	20.69	458.64	63.85	4151.90

T A B L E xvii.

FATIGUE READINGS.

Table xvii. Fatigue Readings.

Subject's number	l	l^2	s	s^2	Hours since rising h	h^2	l + h	$(l + h)^2$	s + h	$(s + h)^2$
1000	32.3	1043.29	19.0	361.00	8	64	40.3	1624.09	27.0	729.00
	26.2	686.44	14.7	216.09	9	81	35.2	1239.04	23.7	561.69
	27.6	761.76	15.7	246.49	7	49	34.6	1197.16	22.7	515.29
	26.2	686.44	16.5	272.25	8	64	34.2	1169.64	24.5	600.25
	23.5	552.25	16.9	285.61	9	81	32.5	1056.25	25.9	670.81
	23.5	552.25	14.8	219.04	8	64	31.5	992.25	22.8	519.84
	25.3	640.09	15.8	249.64	7	49	32.3	1043.29	22.8	519.84
	25.7	660.49	16.3	265.69	8	64	33.7	1135.69	24.3	590.49
	30.0	900.00	15.7	246.49	7	49	37.0	1369.00	22.7	515.25
	26.5	702.25	17.0	289.00	10	100	36.5	1332.25	27.0	729.00
130	34.6	1197.16	18.3	334.89	11	121	45.6	2079.36	29.3	858.49
239	33.7	1135.69	19.0	361.00	11	121	44.7	1998.09	30.0	900.00
678	31.9	1017.61	19.1	364.81	2	4	33.9	1149.21	21.1	445.21
156	31.5	992.25	24.7	610.09	1	1	32.5	1056.25	25.7	660.49
261	29.9	894.01	21.0	441.00	1	1	30.9	954.81	22.0	484.00
20	29.3	858.49	19.7	388.09	11.5	132.25	40.8	1664.64	31.2	973.44
	28.6	817.96	20.6	424.36	11	121	39.6	1568.16	31.6	998.56

Subject's number	l	l^2	s	s^2	Hours since rising h	h^2	l + h	$(l + h)^2$	s + h	$(s + h)^2$
20	27.7	767.29	21.2	449.44	12	144	39.7	1576.09	33.2	1102.24
	30.1	906.01	23.4	547.56	11	121	41.1	1689.21	34.4	1183.36
	28.9	835.21	22.9	524.41	11	121	39.9	1592.01	33.9	1149.21
	32.2	1036.84	22.8	519.84	11.5	132.25	43.7	1909.69	34.3	1176.49
	27.9	778.41	21.8	475.24	11	121	38.9	1513.21	32.8	1075.84
	26.6	707.56	19.6	384.16	6	36	32.6	1062.76	25.6	655.36
	26.2	686.44	19.9	396.01	1	1	27.2	739.84	20.9	436.81
	29.2	852.64	20.9	436.81	1	1	30.2	912.04	21.9	479.61
	28.5	812.25	20.2	408.04	2.5	6.25	31.0	961.00	22.7	515.29
531	30.8	948.64	19.9	396.01	1.5	2.25	32.3	1043.29	21.4	457.96
	31.5	992.25	19.8	392.04	1.5	2.25	33.0	1089.00	21.3	453.69
	30.7	942.49	22.9	524.41	1	1	31.7	1004.89	23.9	571.21
	30.5	930.25	21.6	466.56	1	1	31.5	992.25	22.6	510.76
	29.0	841.00	18.7	349.69	1	1	30.0	900.00	19.7	388.09
	30.7	942.49	21.2	449.44	1.5	2.25	32.2	1036.84	22.7	515.29
	30.4	924.16	19.6	384.16	6	36	36.4	1324.96	25.6	655.36
	28.3	800.89	20.4	416.16	2	4	30.3	918.09	22.4	501.76

Subject's number	l	l^2	s	s^2	Hours since rising h	h^2	l + h	$(l + h)^2$	s + h	$(s + h)^2$
531	29.7	882.09	18.3	334.89	2	4	31.7	1004.89	20.3	412.09
	27.8	772.84	17.1	292.41	2	4	29.8	888.04	19.1	364.81
	32.0	1024.00	19.7	388.09	1.5	2.25	33.5	1122.25	21.2	449.44
280	27.8	772.84	16.3	265.69	2.5	6.25	30.3	918.09	18.8	353.44
	24.8	615.04	17.3	299.29	3	9	27.8	772.84	20.3	412.09
	25.3	640.09	18.4	338.56	2	4	27.3	745.29	20.4	416.16
	27.3	745.29	19.3	372.49	2	4	29.3	858.49	21.3	453.69
	26.0	676.00	18.0	324.00	4	16	30.0	900.00	22.0	484.00
	23.9	571.21	17.8	316.84	1.5	2.25	25.4	645.16	19.3	372.49
	26.8	718.24	18.2	331.24	2	4	28.8	829.44	20.2	408.04
	26.4	696.96	17.1	292.41	1	1	27.4	750.76	18.1	327.61
	24.3	590.49	18.2	331.24	2	4	26.3	691.69	20.2	408.04
	27.5	756.25	17.2	295.84	2.5	6.25	30.0	900.00	19.7	388.09
	25.6	655.36	17.0	289.00	1.5	2.25	27.1	734.41	18.5	342.25
221	32.7	1069.29	19.1	364.81	1.5	2.25	34.2	1169.64	20.6	424.36
	27.3	745.29	19.0	361.00	1	1	28.3	800.89	20.0	400.00
	28.8	829.44	21.9	479.61	3.5	12.25	32.3	1043.29	25.4	645.16

Subject's number	l	l^2	s	s^2	Hours since rising h	h^2	$l + h$	$(l + h)^2$	$s + h$	$(s + h)^2$
221	30.1	906.01	21.2	449.44	1.5	2.25	31.6	998.56	22.7	515.29
	31.1	967.21	22.0	484.00	1.5	2.25	32.6	1062.76	23.5	552.25
	30.2	912.04	23.0	529.00	6.5	42.25	36.7	1346.89	29.5	870.25
	28.2	795.24	20.4	416.16	2	4	30.2	912.04	22.4	501.76
	26.2	686.44	18.3	334.89	2.5	6.25	28.7	823.69	20.8	432.64
	29.2	852.64	20.7	428.49	2.5	6.25	31.7	1004.89	23.2	538.24
	30.3	918.09	21.3	453.69	2	4	32.3	1043.29	23.3	542.89
	29.2	852.64	19.4	376.36	1	1	30.2	912.04	20.4	416.16
530	30.3	918.09	17.9	320.41	2	4	32.3	1043.29	19.9	396.01
	25.0	625.00	19.6	384.16	1	1	26.0	676.00	20.6	424.36
	27.6	761.76	20.3	412.09	1	1	28.6	817.96	21.3	453.69
	24.6	605.16	18.9	357.21	2	4	26.6	707.56	20.9	436.81
	25.7	660.49	17.5	306.25	1	1	26.7	712.89	18.5	342.25
	24.4	595.36	17.6	309.76	1	1	25.4	645.16	18.6	345.96
	21.6	466.56	16.7	278.89	12	144	33.6	1128.96	28.7	823.69
	22.6	510.76	19.3	372.49	12	144	34.6	1197.16	31.3	979.69
	26.4	696.96	17.6	309.76	1	1	27.4	750.76	18.6	345.96

Subject's number	l	l^2	s	s^2	Hours since rising h	h^2	l + h	$(l + h)^2$	s + h	$(s + h)^2$
447	35.0	1225.00	20.6	424.36	2	4	37.0	1369.00	22.6	510.76
	30.1	906.01	21.0	441.00	2	4	32.1	1030.41	23.0	529.00
	28.8	829.44	20.6	424.36	2.5	6.25	31.3	979.69	23.1	533.61
	29.1	846.81	18.4	338.56	1.5	2.25	30.6	936.36	19.9	396.01
	25.5	650.25	17.8	316.84	2.5	6.25	28.0	784.00	20.3	412.09
	28.0	784.00	16.4	268.96	12.5	156.25	40.5	1640.25	28.9	835.21
	27.2	739.84	16.4	268.96	12	144	39.2	1536.64	28.4	806.56
	26.2	686.44	16.2	262.44	12	144	38.2	1459.24	28.2	795.24
	28.8	829.44	18.4	338.56	2	4	30.8	948.64	20.4	416.16
675	30.7	942.49	19.1	364.81	3	9	33.7	1135.69	22.1	488.41
	27.6	761.76	22.7	515.29	2.5	6.25	30.1	906.01	25.2	635.04
	24.5	600.25	20.2	408.04	3	9	27.5	756.25	23.2	538.24
	27.3	745.29	19.6	384.16	12	144	39.3	1544.49	31.6	998.56
	24.2	585.64	16.6	275.56	12	144	36.2	1310.44	28.6	817.96
	28.7	823.69	20.6	424.36	1.5	2.25	30.2	912.04	22.1	488.41
	24.8	615.04	18.9	357.21	12	144	36.8	1354.24	30.9	954.81
	26.8	718.24	19.0	361.00	12	144	38.8	1505.44	31.0	996.00

Subject's number	l	l^2	s	s^2	Hours since rising h	h^2	l + h	$(l + h)^2$	s + h	$(s + h)^2$
675	21.6	466.56	19.7	388.09	1.5	2.25	23.1	533.61	21.2	449.44
	25.0	625.00	19.8	392.04	1.5	2.25	26.5	702.25	21.3	453.69
	22.0	484.00	19.5	380.25	2	4	24.0	576.00	21.5	462.25
611	30.8	948.64	14.1	198.81	7.5	56.25	38.3	1466.89	21.6	466.56
	33.3	1108.89	21.2	449.44	12	144	45.3	2052.09	33.2	1102.24
	30.9	954.81	18.4	338.56	12	144	42.9	1840.41	30.4	924.16
	27.4	750.76	19.9	396.01	11	121	38.4	1474.56	30.9	954.81
	23.1	533.61	17.9	320.41	4	16	27.1	734.41	21.9	479.61
	25.5	650.25	15.9	252.81	12	144	37.5	1406.25	27.9	778.41
	21.8	475.24	17.5	306.25	1	1	22.8	519.84	18.5	342.25
	25.2	635.04	18.8	353.44	4	16	29.2	852.64	22.8	519.84
	25.9	670.81	19.5	380.25	2	4	27.9	778.41	21.5	462.25
520	33.2	1102.24	21.7	470.89	2	4	35.2	1239.04	23.7	561.69
	29.9	894.01	18.8	353.44	3	9	32.9	1082.41	21.8	475.24
	30.3	918.09	20.5	420.25	1.5	2.25	31.8	1011.24	22.0	484.00
	24.5	600.25	19.4	376.36	2	4	26.5	702.25	21.4	457.96

Subject's number	l	l^2	s	s^2	Hours since rising h	h^2	l + h	$(l + h)^2$	s + h	$(s + h)^2$
520	26.2	686.44	20.8	432.64	1.5	2.25	27.7	767.29	22.3	497.29
	26.9	723.61	19.1	364.81	1.5	2.25	28.4	806.56	20.6	424.36
	24.1	580.81	18.1	327.61	2.5	6.25	26.6	707.56	20.6	424.36
	30.5	930.25	21.2	449.44	2	4	32.5	1056.25	23.2	538.24
	29.2	852.64	19.6	384.16	1.5	2.25	30.7	942.49	21.1	445.21
	31.0	961.00	20.6	424.36	2	4	33.0	1089.00	22.6	510.76
422	30.3	918.09	18.9	357.21	2	4	32.3	1043.29	20.9	436.81
	21.1	445.21	16.8	282.24	12	144	33.1	1095.61	28.8	829.44
	26.3	691.69	18.0	324.00	1.5	2.25	27.8	772.84	19.5	380.25
	33.6	1128.96	21.2	449.44	11.5	132.25	45.1	2034.01	32.7	1069.29
	24.9	620.01	20.4	416.16	11.5	132.25	36.4	1324.96	31.9	1017.61
	25.6	655.36	15.5	240.25	11.5	132.25	37.1	1376.41	27.0	729.00
	31.9	1017.61	18.8	353.44	1	1	32.9	1082.41	19.8	392.04
	23.0	529.00	15.2	231.04	1.5	2.25	24.5	600.25	16.7	278.89
	23.7	561.69	16.4	268.96	1.5	2.25	25.2	635.04	17.9	320.41
	21.2	449.44	16.2	262.44	1.5	2.25	22.7	515.29	17.7	313.29
191	26.1	681.21	17.8	316.84	1.5	2.25	27.6	761.76	19.3	372.49

Subject's number	l	l^2	s	s^2	Hours since rising h	h^2	l + h	$(l + h)^2$	s + h	$(s + h)^2$
191	24.2	585.64	17.8	316.84	1	1	25.2	635.04	18.8	353.44
	19.9	396.01	17.0	289.00	10	100	29.9	894.01	27.0	729.00
	21.9	479.61	18.1	327.61	10	100	31.9	1017.61	28.1	789.61
	21.3	453.69	16.5	272.25	2.5	6.25	23.8	566.44	19.0	361.00
355	21.5	462.25	14.8	219.04	4	16	25.5	650.25	18.8	353.44
	23.0	529.00	15.1	228.01	2	4	25.0	625.00	17.1	292.41
	25.6	655.36	17.3	299.29	2	4	27.6	761.76	19.3	372.49
	22.4	501.76	15.4	237.16	3	9	25.4	645.16	18.4	338.56
	23.6	556.96	19.0	361.00	1.5	2.25	25.1	630.01	20.5	420.25
	23.9	571.21	19.9	396.01	1.5	2.25	25.4	645.16	21.4	457.96
	25.6	655.36	20.1	404.01	6	36	31.6	998.56	26.1	681.21
	25.8	665.64	17.8	316.84	12	144	37.8	1428.84	29.8	888.04
	25.6	655.36	18.1	327.61	12	144	37.6	1413.76	30.1	906.01
	25.5	650.25	16.9	285.61	2	4	27.5	756.25	18.9	357.21
378	39.9	1592.01	26.1	681.21	3	9	42.9	1840.41	29.1	846.81
	31.0	961.00	24.2	585.64	2	4	33.0	1089.00	26.2	686.44
	29.8	888.04	19.2	368.64	3	9	32.8	1075.84	22.2	492.84

Subject's number	l	l^2	s	s^2	Hours since rising h	h^2	l + h	$(l + h)^2$	s + h	$(s + h)^2$
378	28.2	795.24	21.9	479.61	1.5	2.25	29.7	882.09	23.4	547.56
	29.1	846.81	24.1	580.81	1	1	30.1	906.01	25.1	630.01
	27.1	734.41	24.8	615.04	1.5	2.25	28.6	817.96	26.3	691.69
	27.2	739.84	22.2	492.84	2.5	6.25	29.7	882.09	24.7	610.09
	30.3	918.09	23.4	547.56	3	9	33.3	1108.89	26.4	696.96
	30.8	948.64	24.8	615.04	2	4	32.8	1075.84	26.8	718.24
103	29.3	858.49	19.8	392.04	11	121	40.3	1624.09	30.8	948.64
	31.0	961.00	20.2	408.04	10.5	110.25	41.5	1722.25	30.7	942.49
	26.9	723.61	21.2	449.44	11	121	37.9	1436.41	32.2	1036.84
	26.5	702.25	18.8	353.44	10.5	110.25	37.0	1369.00	29.3	858.49
	25.9	670.81	16.3	265.69	2	4	27.9	778.41	18.3	334.89
	22.0	484.00	17.0	289.00	1.5	2.25	23.5	552.25	18.5	342.25
	23.0	529.00	18.6	345.96	2	4	25.0	625.00	20.6	424.36
	22.5	506.25	19.5	380.25	2.5	6.25	25.0	625.00	22.0	484.00
	23.2	538.24	16.4	268.96	1	1	24.2	585.64	17.4	302.76
	23.6	556.96	16.6	275.56	1.5	2.25	25.1	630.01	18.1	327.61

Subject's number	l	l^2	s	s^2	Hours since rising h	h^2	l + h	$(l + h)^2$	s + h	$(s + h)^2$
103	34.1	1162.81	15.3	234.09	2	4	36.1	1303.21	17.3	299.29
27	29.6	876.16	15.2	231.04	11.5	132.25	41.1	1689.21	26.7	712.89
	25.9	670.81	17.5	306.25	9.5	90.25	35.4	1253.16	27.0	729.00
	29.3	858.49	17.9	320.41	9.5	90.25	38.8	1505.44	27.4	750.76
	25.2	635.04	18.5	342.25	9.5	90.25	34.7	1204.09	28.0	784.00
	34.2	1169.64	18.7	349.69	4	16	38.2	1459.24	22.7	515.29
	29.6	876.16	17.7	313.29	1	1	30.6	936.36	18.7	349.69
	30.5	930.25	19.2	368.64	1	1	31.5	992.25	20.2	408.04
	29.8	888.04	17.6	309.76	2	4	31.8	1011.24	19.6	384.16
	32.0	1024.00	16.8	282.24	1.5	2.25	33.5	1122.25	18.3	334.89
	33.0	1089.00	18.8	353.44	6	36	39.0	1521.00	24.8	615.04
	36.3	1317.69	18.6	345.96	2	4	38.3	1466.89	20.6	424.36
243	28.2	795.24	16.8	282.24	2	4	30.2	912.04	18.8	353.44
	29.3	858.49	15.2	231.04	1	1	30:3	918.09	16.2	262.44
	28.0	784.00	15.2	231.04	1.5	2.25	29.5	870.25	16.7	278.89
	23.9	571.21	15.0	225.00	1	1	24.9	620.01	16.0	256.00
	22.2	492.84	14.8	219.04	2.5	6.25	24.7	610.09	17.3	299.29

Subject's number	l	l^2	s	s^2	Hours since rising h	h^2	l + h	$(l + h)^2$	s + h	$(s + h)^2$
243	24.2	585.64	14.5	210.25	2	4	26.2	686.44	16.5	272.25
	22.2	492.84	15.0	225.00	1	1	23.2	538.24	16.0	256.00
	22.5	506.25	14.7	216.09	2	4	24.5	600.25	16.7	278.89
	29.7	882.09	13.3	176.89	15	225	44.7	1998.09	28.3	800.89
	26.1	681.21	12.2	148.84	6	36	32.1	1030.41	18.2	331.24
	27.7	767.29	12.4	153.76	5.5	30.25	33.2	1102.24	17.9	320.41
	29.8	888.04	12.1	146.41	2	4	31.8	1011.24	14.1	198.81
209	29.4	864.36	19.4	376.36	11	121	40.4	1632.16	30.4	924.16
	24.8	615.04	18.8	353.44	10	100	34.8	1211.04	28.8	829.44
	26.6	707.56	17.7	313.29	11	121	37.6	1413.76	28.7	823.69
	21.6	466.56	17.6	309.76	2	4	23.6	556.96	19.6	384.16
	28.5	812.25	19.4	376.36	1	1	29.5	870.25	20.4	416.16
	27.6	761.76	19.6	384.16	1	1	28.6	817.96	20.6	424.36
	27.0	729.00	20.8	432.64	1.5	2.25	28.5	812.25	22.3	497.29
	31.6	998.56	18.1	327.61	1.5	2.25	33.1	1095.61	19.6	384.16
	34.0	1156.00	19.5	380.25	3.5	12.25	37.5	1406.25	23.0	529.00
	25.1	630.01	19.2	368.64	4.5	20.25	29.6	876.16	23.7	561.69

Subject's number	l	l^2	s	s^2	Hours since rising h	h^2	l + h	$(l + h)^2$	s + h	$(s + h)^2$
209	28.2	795.24	19.6	384.16	1	1	29.2	852,64	20.6	424.36
529	27.4	750.76	18.5	342.25	11	121	38.4	1474.56	29.5	870.25
	25.8	665.64	14.3	204.49	8.5	72.25	34.3	1176.49	22.8	519.84
	20.5	420.25	14.5	210.25	8	64	28.5	812.25	22.5	506.25
	21.0	441.00	15.0	225.00	3	9	24.0	576.00	18.0	324.00
	21.9	479.61	15.8	249.64	2	4	23.9	571.21	17.8	316.84
	20.4	416.16	14.6	213.16	2	4	22.4	501.76	16.6	275.56
	21.7	470.89	14.4	207.36	3	9	24.7	610.09	17.4	302.76
	20.4	416.16	14.7	216.09	4	16	24.4	595.36	18.7	349.69
	19.6	384.16	13.9	193.21	3	9	22.6	510.76	16.9	285.61
	19.9	396.01	13.6	184.96	4.5	20.25	24.4	595.36	18.1	327.61
	19.0	361.00	14.0	196.00	2	4	21.0	441.00	16.0	256.00
71	25.3	640.09	17.6	309.76	3	9	28.3	800.89	20.6	424.36
	26.0	676.00	17.5	306.25	1.5	2.25	27.5	756.25	19.0	361.00
	22.6	510.76	16.1	259.21	2	4	24.6	605.16	18.1	327.61
	26.1	681.21	19.3	372.49	21.5	462.25	47.6	2265.76	40.8	1664.64
	24.7	610.09	17.1	292.41	2	4	26.7	712.89	19.1	364.81

Subject's number	l	l^2	s	s^2	Hours since rising h	h2	l + h	$(l + h)^2$	s + h	$(s + h)^2$
71	24.7	610.09	17.2	295.84	3.5	12.25	28.2	795.24	20.7	428.49
	22.6	510.76	18.5	342.25	2	4	24.6	605.16	20.5	420.25
	29.6	876.16	19.3	372.49	2	4	31.6	998.56	21.3	453.69
	33.7	1135.69	17.0	289.00	1.5	2.25	35.2	1239.04	18.5	342.25
	32.2	1036.84	18.3	334.89	2	4	34.2	1169.64	20.3	412.09
	32.0	1024.00	17.9	320.41	2	4	34.0	1156.00	19.9	396.01
524	38.2	1459.24	15.7	246.49	5.5	30.25	43.7	1909.69	21.2	449.44
	37.1	1376.41	12.6	158.76	1	1	38.1	1451.61	13.6	184.96
	35.2	1239.04	16.0	256.00	1	1	36.2	1310.44	17.0	289.00
	32.3	1043.29	14.4	207.36	1	1	33.3	1108.89	15.4	237.16
	31.6	998.56	15.6	243.36	1.5	2.25	33.1	1095.61	17.1	292.41
	30.9	954.81	14.7	216.09	2.5	6.25	33.4	1115.56	17.2	295.84
	32.5	1056.25	14.8	219.04	1.5	2.25	34.0	1156.00	16.3	265.69
	30.2	912.04	12.6	158.76	1.5	2.25	31.7	1004.89	14.1	198.81
	34.5	1190.25	19.2	368.64	2	4	36.5	1332.25	21.2	449.44
	34.6	1197.16	16.4	268.96	1.5	2.25	36.1	1303.21	17.9	320.41

Subject's number	l	l^2	s	s^2	Hours since rising h	h^2	l + h	$(l + h)^2$	s + h	$(s + h)^2$
524	33.7	1135.69	17.8	316.84	1	1	34.7	1204.09	18.8	353.44
8	30.8	948.64	13.3	176.89	2	4	32.8	1075.84	15.3	234.09
678	32.2	1036.84	18.0	324.00	2	4	34.2	1169.64	20.0	400.00
572	35.3	1246.09	17.4	302.76	6	36	41.3	1705.69	23.4	547.56
683	31.4	985.96	22.6	510.76	2	4	33.4	1115.56	24.6	605.16
239	33.2	1102.24	24.9	620.01	1.5	2.25	34.7	1204.09	26.4	696.96
250	33.1	1095.61	14.8	219.04	1.5	2.25	34.6	1197.16	16.3	265.69
359	29.7	882.09	16.3	265.69	12	144	41.7	1738.89	28.3	800.89
526	32.5	1056.25	20.4	416.16	2	4	34.5	1190.25	22.4	501.76
24	37.4	1398.76	18.8	353.44	2.5	6.25	39.9	1592.01	21.3	453.69
342	34.7	1204.09	19.4	376.36	2	4	36.7	1346.89	21.4	457.96
156	28.2	795.24	17.6	309.76	1	1	29.2	852.64	18.6	345.96
130	29.5	870.25	14.8	219.04	1.5	2.25	31.0	961.00	16.3	265.69
527	33.3	1108.89	20.5	420.25	12.5	156.25	45.8	2097.64	33.0	1089.00
680	38.8	1505.44	22.5	506.25	2	4	40.8	1664.64	24.5	600.25
556	26.1	1303.21	19.1	364.81	1	1	27.1	734.41	20.1	404.01
54	29.7	882.09	21.0	441.00	1.5	2.25	31.2	973.44	22.5	506.25

Subject's number	l	l^2	s	s^2	Hours since rising h	h^2	l + h	$(l + h)^2$	s + h	$(s + h)^2$
310	32.2	1036.84	18.1	327.61	2.5	6.25	34.7	1204.09	20.6	424.36
146	33.0	1089.00	18.4	338.56	1	1	34.0	1156.00	19.4	376.36
268	25.8	665.64	19.8	392.04	2	4	27.8	772.84	21.8	475.24
213	33.6	1128.96	28.3	800.89	12	144	45.6	2079.36	40.3	1624.09
483	28.2	795.24	18.0	324.00	1.5	2.25	29.7	882.09	19.5	380.25
681	32.8	1075.84	20.7	428.49	2	4	34.8	1211.04	22.7	515.29
374	27.4	750.76	17.6	309.76	2.5	6.25	29.9	894.01	20.1	404.01
557	23.2	538.24	17.0	289.00	2	4	25.2	635.04	19.0	361.00
543	33.9	1149.21	23.8	566.44	1	1	34.9	1218.01	24.8	615.04
552	23.6	556.96	17.0	289.00	2	4	25.6	655.36	19.0	361.00
	25.6	655.36	16.5	272.25	11	121	36.6	1339.56	27.5	756.25
	22.4	501.76	16.8	282.24	2	4	24.4	595.36	18.8	353.44
	23.4	547.56	16.2	262.44	11	121	34.4	1183.36	27.2	739.84
	25.0	625.00	16.4	268.96	2	4	27.0	729.00	18.4	338.56
	24.0	576.00	15.4	237.16	11	121	35.0	1225.00	26.4	696.96
	23.2	538.24	17.6	309.76	2	4	25.2	635.04	19.6	384.16
	23.6	556.96	16.2	262.44	11	121	34.6	1197.16	27.2	739.84

Subject's number	l	l^2	s	s^2	Hours since rising h	h^2	l + h	$(l + h)^2$	s + h	$(s + h)^2$
552	24.0	576.00	17.4	302.76	2	4	26.0	676.00	19.4	376.36
	23.6	556.96	17.0	289.00	11	121	34.6	1197.16	28.0	784.00
426	34.6	1197.16	16.2	262.44	1.5	2.25	36.1	1303.21	17.7	313.29
	33.2	1102.24	18.7	349.69	10	100	43.2	1866.24	28.7	823.69
	28.8	829.44	17.4	302.76	1.5	2.25	30.3	918.09	18.9	357.21
	28.1	789.61	16.0	256.00	10	100	38.1	1451.61	26.0	676.00
	29.1	846.81	16.6	275.56	1.5	2.25	30.6	936.36	18.1	327.61
	24.5	600.25	15.4	237.16	10	100	34.5	1190.25	25.4	645.16
	24.4	595.36	18.2	331.24	1.5	2.25	25.9	670.81	19.7	388.09
	23.5	552.25	16.2	262.44	10	100	33.5	1122.25	26.2	686.44
	24.0	576.00	15.6	243.36	1.5	2.25	25.5	650.25	17.1	292.41
	21.4	457.96	15.3	234.09	10	100	31.4	985.96	25.3	640.09
360	29.5	870.25	20.0	400.00	2	4	31.5	992.25	22.0	484.00
	29.1	846.81	18.4	338.56	10.5	110.25	39.6	1568.16	28.9	835.21
	27.9	778.41	20.0	400.00	2	4	29.9	894.01	22.0	484.00
	28.3	800.89	18.5	342.25	10.5	110.25	38.8	1505.44	29.0	841.00
	31.9	1017.61	20.8	432.64	2	4	33.9	1149.21	22.8	519.84

Subject's number	l	l^2	s	s^2	Hours since rising h	h^2	l + h	$(l + h)^2$	s + h	$(s + h)^2$
360	30.8	948.64	20.7	428.49	10.5	110.25	41.3	1705.69	31.2	973.44
	29.0	841.00	21.3	453.69	1.5	2.25	30.5	930.25	22.8	519.84
	30.2	912.04	21.8	475.24	10.5	110.25	40.7	1656.49	32.3	1043.29
	33.1	1095.61	25.0	625.00	1.5	2.25	34.6	1197.16	26.5	702.25
	34.0	1156.00	20.6	424.36	11	121	45.0	2025.00	31.6	998.56
660	26.6	707.56	16.2	262.44	1.5	2.25	28.1	789.61	17.7	313.29
	25.4	645.16	14.8	219.04	10.5	110.25	35.9	1288.81	25.3	640.09
	25.3	640.09	18.2	331.24	1.5	2.25	26.8	718.24	19.7	388.09
	24.8	615.04	16.1	259.21	10	100	34.8	1211.04	26.1	681.21
	21.8	475.24	15.7	246.49	1.5	2.25	23.3	542.89	17.2	295.84
	27.8	772.84	20.0	400.00	10.5	110.25	38.3	1466.89	30.5	930.25
	24.8	615.04	18.3	334.89	1.5	2.25	26.3	691.69	19.8	392.04
	21.8	475.24	16.9	285.61	10.5	110.25	32.3	1043.29	27.4	750.76
	22.1	488.41	15.9	252.81	1.5	2.25	23.6	556.96	17.4	302.76
	22.7	515.29	16.6	275.56	10	100	32.7	1069.29	26.6	707.56
607	31.0	961.00	19.0	361.00	1.5	2.25	32.5	1056.25	20.5	420.25
	28.3	800.89	16.9	285.61	10	100	38.3	1466.89	26.9	723.61

Subject's number	l	l^2	s	s^2	Hours since rising h	h^2	l + h	$(l + h)^2$	s + h	$(s + h)^2$
607	29.1	846.81	19.6	384.16	2	4	31.1	967.21	21.6	466.56
	30.1	906.01	24.9	620.01	10.5	110.25	40.6	1648.36	35.4	1253.16
	27.2	739.84	17.9	320.41	1.5	2.25	28.7	823.69	19.4	376.36
	27.4	750.76	18.1	327.61	10	100	37.4	1398.76	28.1	789.61
	28.0	784.00	23.9	571.21	1.5	2.25	29.5	870.25	25.4	645.16
	27.2	739.84	18.3	334.89	10.5	110.25	37.7	1421.29	28.8	829.44
429	28.1	789.61	18.1	327.61	2	4	30.1	906.01	20.1	404.01
	27.8	772.84	16.8	282.24	10	100	37.8	1428.84	26.8	718.24
	25.2	635.04	15.9	252.81	2	4	27.2	739.84	17.9	320.41
	25.1	630.01	14.4	207.36	10.5	110.25	35.6	1267.36	24.9	620.01
	23.0	529.00	15.5	240.25	2	4	25.0	625.00	17.5	306.25
	27.1	734.41	15.7	246.49	10	100	37.1	1376.41	25.7	660.49
	26.3	691.69	15.9	252.81	2.5	6.25	28.8	829.44	18.4	338.56
	26.5	702.25	18.7	349.69	11	121	37.5	1406.25	29.7	882.09
1001	28.3	800.89	16.3	265.69	1.5	2.25	29.8	888.04	17.8	316.84
	23.4	547.56	15.2	231.04	10	100	33.4	1115.56	25.2	635.04

Subject's number	l	l^2	s	s^2	Hours since rising h	h^2	l + h	$(l + h)^2$	s + h	$(s + h)^2$
1001	24.8	615.04	16.8	282.24	1.5	2.25	26.3	691.69	18.3	334.89
	24.0	576.00	17.2	295.84	10	100	34.0	1156.00	27.2	739.84
	23.7	561.69	14.9	222.01	1.5	2.25	25.2	635.04	16.4	268.96
	24.6	605.16	14.9	222.01	9.5	90.25	34.1	1162.81	24.4	585.64
	24.7	610.09	16.8	282.24	1.5	2.25	26.2	686.44	18.3	334.89
	23.0	529.00	15.5	240.25	10	100	33.0	1089.00	25.5	650.25
1002	34.7	1204.09	22.2	492.84	1.5	2.25	36.2	1310.44	23.7	561.69
	37.7	1421.29	30.4	924.16	10.5	110.25	48.2	2323.24	40.9	1672.81
	31.8	1011.24	25.8	665.64	1.5	2.25	33.3	1108.89	27.3	745.29
	34.5	1190.25	21.6	466.56	10.5	110.25	45.0	2025.00	32.1	1030.41
	32.1	1030.41	20.6	424.36	2	4	34.1	1162.81	22.6	510.76
	28.6	817.96	19.4	376.36	10.5	110.25	39.1	1528.81	29.9	894.01
	30.6	936.36	20.2	408.04	1.5	2.25	32.1	1030.41	21.7	470.89
	27.2	739.84	20.6	424.36	11	121	38.2	1459.24	31.6	998.56
547	27.7	767.29	18.4	338.56	2	4	29.7	882.09	20.4	416.16
	27.0	729.00	20.5	420.25	10	100	37.0	1369.00	30.5	930.25
	27.9	778.41	21.6	466.56	2	4	29.9	894.01	23.6	556.96

Subject's number	l	l^2	s	s^2	Hours since rising h	h^2	$l + h$	$(l + h)^2$	$s + h$	$(s + h)^2$
547	30.8	948.64	20.7	428.49	10	100	40.8	1664.64	30.7	942.49
	32.9	1082.41	24.0	576.00	2	4	34.9	1218.01	26.0	676.00
	29.6	876.16	20.0	400.00	10	100	39.6	1568.16	30.0	900.00
	29.6	876.16	20.2	408.04	2	4	31.6	998.56	22.2	492.84
	30.3	918.09	21.6	466.56	10.5	110.25	40.8	1664.64	32.1	1030.41
500	34.0	1156.00	19.9	396.01	2	4	36.0	1296.00	21.9	479.61
	34.2	1169.64	19.2	368.64	10.5	110.25	44.7	1998.09	29.7	882.09
	29.8	888.04	17.5	306.25	2.5	6.25	32.3	1043.29	20.0	400.00
	32.2	1036.84	17.4	302.76	10.5	110.25	42.7	1823.29	27.9	778.41
	30.2	912.04	18.9	357.21	2	4	32.2	1036.84	20.9	436.81
	29.7	882.09	21.2	449.44	11	121	40.7	1656.49	32.2	1036.84
	29.9	894.01	18.8	353.44	2.5	6.25	32.4	1049.76	21.3	453.69
	29.0	841.00	19.6	384.16	11.5	132.25	40.5	1640.25	31.1	967.21
	26.7	712.89	20.4	416.16	2.5	6.25	29.2	852.64	22.9	524.41
	30.5	930.25	26.3	691.69	10.5	110.25	41.0	1681.00	36.8	1354.24
186	27.4	750.76	20.6	424.36	2	4	29.4	864.36	22.6	510.76
	30.1	906.01	19.6	384.16	10.5	110.25	40.6	1648.36	30.1	906.01

Subject's number	l	l^2	s	s^2	Hours since rising h	h^2	l + h	$(l + h)^2$	s + h	$(s + h)^2$
186	27.4	750.76	19.0	361.00	1.5	2.25	28.9	835.21	20.5	420.25
	29.6	876.16	25.6	655.36	10.5	110.25	40.1	1608.01	36.1	1303.21
	28.7	823.69	22.9	524.41	2	4	30.7	942.49	24.9	620.01
	27.3	745.29	21.8	475.24	10.5	110.25	37.8	1428.84	32.3	1043.29
	25.2	635.04	17.8	316.84	1.5	2.25	26.7	712.89	19.3	372.41
	25.2	635.04	19.5	380.25	10.0	100	35.2	1239.04	29.5	870.25
	25.0	625.00	19.7	388.09	2	4	27.0	729.00	21.7	470.89
	28.7	823.69	23.0	529.00	10.5	110.25	39.2	1536.64	33.5	1122.25
1007	32.6	1062.76	16.8	282.24	1.5	2.25	34.1	1162.81	18.3	334.89
	32.3	1043.29	16.2	262.44	10.5	110.25	42.8	1831.84	26.7	712.89
	27.9	778.41	15.9	252.81	1.5	2.25	29.4	864.36	17.4	302.76
	31.5	992.25	16.0	256.00	10.5	110.25	42.0	1764.00	26.5	702.25
	31.7	1004.89	15.7	246.49	1.5	2.25	33.2	1102.24	17.2	295.84
	30.7	942.49	16.2	262.44	10.5	110.25	41.2	1697.44	26.7	712.89
	29.7	882.09	16.4	268.96	1.5	2.25	31.2	973.44	17.9	320.41
	27.9	778.41	16.1	259.21	11.0	121	38.9	1513.21	27.1	734.41
	31.5	992.25	20.2	408.04	1.5	2.25	33.0	1089.00	21.7	470.89

Subject's number	1	1^2	s	s^2	Hours since rising h	h^2	1 + h	$(1 + h)^2$	s + h	$(s + h)^2$
1007	29.5	870.25	19.4	376.36	10.5	110.25	40.0	1600.00	29.9	894.01
667	29.8	888.04	16.5	272.25	1.5	2.25	31.3	979.69	18.0	324.00
	28.7	823.69	15.4	237.16	9.5	90.25	38.2	1459.24	24.9	620.01
	31.7	1004.89	16.9	285.61	1.5	2.25	33.2	1102.24	18.4	338.56
	30.4	924.16	14.8	219.04	9.5	90.25	39.9	1592.01	24.3	590.49
	30.0	900.00	16.5	272.25	1.5	2.25	31.5	992.25	18.0	324.00
	28.7	823.69	14.5	210.25	9.5	90.25	38.2	1459.24	24.0	576.00
	29.9	894.01	15.7	246.49	1.5	2.25	31.4	985.96	17.2	295.84
	29.3	858.49	14.7	216.09	9.5	90.25	38.8	1505.44	24.2	585.64
	29.0	841.00	14.6	213.16	1.5	2.25	30.5	930.25	16.1	259.21
	28.4	806.56	15.0	225.00	9.5	90.25	37.9	1436.41	24.5	600.25
19	30.0	900.00	25.2	635.04	1.5	2.25	31.5	992.25	26.7	712.89
	30.5	930.25	22.7	515.29	9.5	90.25	40.0	1600.00	32.2	1036.84
	29.9	894.01	20.9	436.81	1.5	2.25	31.4	985.96	22.4	501.76
	33.1	1095.61	27.0	729.00	10.0	100	43.1	1857.61	37.0	1369.00
	29.7	882.09	22.4	501.76	1.5	2.25	31.2	973.44	23.9	571.21
	33.4	1115.56	24.6	605.16	10	100	43.4	1883.56	34.6	1197.16

Subject's number	l	l^2	s	s^2	Hours since rising h	h^2	l + h	$(l + h)^2$	s + h	$(s + h)^2$
19	33.0	1089.00	25.3	640.09	1.5	2.25	34.5	1190.25	26.8	718.24
	35.8	1281.64	25.2	635.04	10.5	110.25	46.3	2143.69	35.7	1274.49
69	34.5	1190.25	19.8	392.04	1.5	2.25	36.0	1296.00	21.3	453.69
	35.5	1260.25	20.0	400.00	9.5	90.25	45.0	2025.00	29.5	870.25
	33.2	1102.24	20.8	432.64	1.5	2.25	34.7	1204.09	22.3	497.29
	34.6	1197.16	19.9	396.01	10	100	44.6	1989.16	29.9	894.01
	35.2	1239.04	21.3	453.69	1.5	2.25	36.7	1346.89	22.8	519.84
	35.5	1260.25	19.7	388.09	9.5	90.25	45.0	2025.00	29.2	852.64
	34.9	1218.01	21.6	466.56	1.5	2.25	36.4	1324.96	23.1	533.61
	36.7	1346.89	20.8	432.64	9.5	90.25	46.2	2134.44	30.3	918.09
	34.0	1156.00	20.9	436.81	1.5	2.25	35.5	1260.25	22.4	501.76
	36.1	1303.21	22.4	501.76	9.5	90.25	45.6	2079.36	31.9	1017.61
308	39.3	1544.49	21.4	457.96	2	4	41.3	1705.69	23.4	547.56
	36.1	1303.21	19.2	368.64	10	100	46.1	2125.21	29.2	852.64
	33.0	1089.00	19.4	376.36	1.5	2.25	34.5	1190.25	20.9	436.81
	36.5	1332.25	20.1	404.01	10	100	46.5	2162.25	30.1	906.01

Subject's number	l	l^2	s	s^2	Hours since rising h	h^2	l + h	$(l + h)^2$	s + h	$(s + h)^2$
308	33.9	1149.21	19.1	364.81	2	4	35.9	1288.81	21.1	445.21
	37.0	1369.00	19.2	368.64	10	100	47.0	2209.00	29.2	852.64
	34.7	1204.09	18.9	357.21	2	4	36.7	1346.89	20.9	436.81
	37.8	1428.84	20.4	416.16	10	100	47.8	2284.84	30.4	924.16
	38.9	1513.21	21.8	475.24	2	4	40.9	1672.81	23.8	566.44
	39.3	1544.49	23.6	556.96	10	100	49.3	2430.49	33.6	1128.96
117	34.0	1156.00	21.6	466.56	9	81	43.0	1849.00	30.6	936.36
604	26.5	702.25	19.2	368.64	2	4	28.5	812.25	21.2	449.44
418	32.2	1036.84	18.2	331.24	2	4	34.2	1169.64	20.2	408.04
202	33.0	1089.00	18.2	331.24	1.5	2.25	34.5	1190.25	19.7	388.09
262	32.9	1082.41	20.0	400.00	12.5	156.25	45.4	2061.16	32.5	1056.25
539	30.4	924.16	19.0	361.00	1.5	2.25	31.9	1017.61	20.5	420.25
608	28.0	784.00	15.0	225.00	2.5	6.25	30.5	930.25	17.5	306.25
528	31.4	985.96	18.4	338.56	12	144	43.4	1883.56	30.4	924.16
216	30.4	924.16	18.2	331.24	2	4	32.4	1049.76	20.2	408.04
212	33.7	1135.69	22.3	497.29	1.5	2.25	35.2	1239.04	23.8	566.44
	31.1	967.21	21.5	462.25	10.5	110.25	41.6	1730.56	32.0	1024.00

Subject's number	l	l^2	s	s^2	Hours since rising h	h^2	l + h	$(l + h)^2$	s + h	$(s + h)^2$
212	29.0	841.00	20.0	400.00	1.5	2.25	30.5	930.25	21.5	462.25
	31.9	1017.61	22.9	524.41	10.5	110.25	42.4	1797.76	33.4	1115.56
	28.9	835.21	20.2	408.04	1.5	2.25	30.4	924.16	21.7	470.89
	32.4	1049.76	21.2	449.44	10.5	110.25	42.9	1840.41	31.7	1004.89
591	42.3	1789.29	25.8	665.64	1.5	2.25	43.8	1918.44	27.3	745.29
	32.1	1030.41	23.0	529.00	10	100	42.1	1772.41	33.0	1089.00
	33.0	1089.00	23.3	542.89	1.5	2.25	34.5	1190.25	24.8	615.04
	27.7	767.29	20.2	408.04	10	100	37.7	1421.29	30.2	912.04
	24.0	576.00	17.5	306.25	1.5	2.25	25.5	650.25	19.0	361.00
	25.6	655.36	15.8	249.64	10.5	110.25	36.1	1303.21	26.3	691.69
623	32.1	1030.41	21.5	462.25	1.5	2.25	33.6	1128.96	23.0	529.00
	39.9	1592.01	23.3	542.89	10	100	49.9	2490.01	33.3	1108.89
	35.2	1239.04	23.7	561.69	1.5	2.25	36.7	1346.89	25.2	635.04
	35.6	1267.36	21.7	470.89	10	100	45.6	2079.36	31.7	1004.89
	31.0	961.00	23.3	542.89	1.5	2.25	32.5	1056.25	24.8	615.04
	31.7	1004.89	19.4	376.36	10	100	41.7	1738.89	29.4	864.36
368	22.9	524.41	17.0	289.00	2	4	24.9	620.01	19.0	361.00

Subject's number	l	l^2	s	s^2	Hours since rising h	h^2	l + h	$(l + h)^2$	s + h	$(s + h)^2$
107	30.8	948.64	23.2	538.24	12	144	42.8	1831.84	35.2	1239.04
682	24.7	610.09	17.4	302.76	3.5	12.25	28.2	795.24	20.9	436.81
162	25.1	630.01	18.0	324.00	12.0	124.00	37.1	1376.41	30.0	900.00
<u>TOTAL</u> 423	12107.6	354608.78	7925.2	151936.94	2106.0	18084.00	14213.6	492912.18	10031.2	249309.00
<u>MEAN</u>	28.6	838.32	18.7	359.19	4.9	42.75	33.6	1165.27	23,7	589.38

T A B L E xviii.

EFFECT OF PROXIMITY TO A MEAL.

Table xviii Effect of Proximity to Meal.

Subject's number	l	l^2	s	s^2	Time since last meal M	M^2	l + m	$(l + m)^2$	s + m	$(s + m)^2$
20	29.3	858.49	19.7	388.09	1.5	2.25	30.8	948.64	21.2	449.44
	28.6	817.96	20.6	424.36	1.0	1.0	29.6	876.16	21.6	466.56
	27.7	767.29	21.2	449.44	1.25	1.5625	28.95	838.1025	22.45	504.0025
	30.1	906.01	23.4	547.56	1.33	1.7689	31.43	987.8449	24.73	611.5729
	28.9	835.21	22.9	524.41	1.0	1.0	29.9	894.01	23.9	571.21
	32.2	1036.84	22.8	519.84	1.0	1.0	33.2	1102.24	23.8	566.44
	27.9	778.41	21.8	475.24	1.0	1.0	28.9	835.21	22.8	519.84
	26.6	707.56	19.6	384.16	3.0	9.0	29.6	841.00	22.6	517.76
	26.2	686.44	19.9	396.01	14.0	196.00	40.2	1616.04	33.9	1149.21
	29.2	852.64	20.9	436.81	0.5	0.25	29.7	882.09	21.4	457.96
	28.5	812.25	20.2	408.04	2.0	4.0	30.5	930.25	22.2	492.84
531	30.8	948.64	19.9	396.01	1.0	1.0	31.8	1011.24	20.9	436.81
	31.5	992.25	19.8	392.04	1.0	1.0	32.5	1056.25	20.8	432.64
	30.7	942.49	22.9	524.41	1.0	1.0	31.7	1004.89	23.9	571.21
	30.5	930.25	21.6	466.56	0.75	0.5625	31.25	976.5625	22.35	499.5225
	29.0	841.00	18.7	349.69	1.0	1.0	30.0	900.00	19.7	388.09

Subject's number	l	l^2	s	s^2	Time since last meal m	m^2	l + m	$(l + m)^2$	s + m	$(s + m)^2$
531	30.7	942.49	21.2	449.44	1.0	1.0	31.7	1004.89	22.2	492.84
	30.4	924.16	19.6	384.16	4.25	18.0625	34.65	1200.6225	23.85	568.8225
	28.3	800.89	20.4	416.16	1.0	1.0	29.3	858.49	21.4	457.96
	29.7	882.09	18.3	334.89	1.0	1.0	30.7	942.49	19.3	372.49
	27.8	772.84	17.1	292.41	1.0	1.0	28.8	829.44	18.1	327.61
	32.0	1024.00	19.7	388.09	1.0	1.0	33.0	1089.00	20.7	428.49
280	27.8	772.84	16.3	265.69	2.5	6.25	30.3	918.09	18.8	353.44
	24.8	615.04	17.3	299.29	2.5	6.25	27.3	745.29	19.8	392.04
	25.3	640.09	18.4	338.56	2.25	5.0625	27.55	759.0025	20.65	426.4225
	27.3	745.29	19.3	372.49	1.75	3.0625	29.05	843.9025	21.05	443.1025
	26.0	676.00	18.0	324.00	3.5	12.25	29.5	870.25	21.5	462.25
	23.9	571.21	17.8	316.84	1.0	1.0	24.9	620.01	18.8	353.44
	26.8	718.24	18.2	331.24	1.0	1.0	27.8	772.84	19.2	368.64
	26.4	696.96	17.1	292.41	1.0	1.0	27.4	750.76	18.1	327.61
	24.3	590.49	18.2	331.24	2.0	4.0	26.3	691.69	20.2	408.04
	27.5	756.25	17.2	295.84	2.5	6.25	30.0	900.00	19.7	388.09
	25.6	655.36	17.0	289.00	1.5	2.25	27.1	734.41	18.5	342.25

Subject's number	l	l^2	s	s^2	Time since last meal m	m^2	l + m	$(l + m)^2$	s + m	$(s + m)^2$
221	32.7	1069.29	19.1	364.81	1.0	1.0	33.7	1135.69	20.1	404.01
	27.3	745.29	19.0	361.00	0.66	0.4356	27.96	781.7616	19.66	386.5156
	28.8	829.44	21.9	479.61	2.5	6.25	31.3	979.69	24.4	595.36
	30.1	906.01	21.2	449.44	1.0	1.0	31.1	967.21	22.2	492.84
	31.1	967.21	22.0	484.00	1.25	1.5625	32.35	1046.5225	23.25	540.5625
	30.2	912.04	23.0	529.00	3.25	10.5625	33.45	1118.9025	26.25	689.0625
	28.2	795.24	20.4	416.16	1.25	1.5625	29.45	867.3025	21.65	468.7225
	26.2	686.44	18.3	333.89	1.0	1.0	27.2	739.84	19.3	372.49
	29.2	852.64	20.7	428.49	1.5	2.25	30.7	942.49	22.2	492.84
	30.3	918.09	21.3	453.69	1.25	1.5625	31.55	995.4025	22.55	508.5025
	29.2	852.64	19.4	376.36	0.5	0.25	29.7	882.09	19.9	396.01
530	30.3	918.09	17.9	320.41	1.5	2.25	31.8	1011.24	19.4	376.36
	25.0	625.00	19.6	384.16	0.75	0.5625	25.75	663.0625	20.35	414.1225
	27.6	761.76	20.3	412.09	0.75	0.5625	28.35	803.7225	21.05	443.1025
	24.6	605.16	18.9	357.21	1.0	1.0	25.6	655.36	19.9	396.01
	25.7	660.49	17.5	306.25	0.5	0.25	26.2	686.44	18.0	324.00
	24.4	595.36	17.6	309.76	0.5	0.25	24.9	620.01	18.1	327.61

Subject's number	l	l^2	s	s^2	Time since last meal m	m^2	l + m	$(l + m)^2$	s + m	$(s + m)^2$
530	19.8	392.04	15.6	243.36	4.5	20.25	24.3	590.49	20.1	404.01
	21.6	466.56	16.7	278.89	2.0	4.0	23.6	556.96	18.7	349.69
	22.6	510.76	19.3	372.49	2.5	6.25	25.1	630.01	21.8	475.24
	26.4	696.96	17.6	309.76	1.0	1.0	27.4	750.76	18.6	345.96
447	35.0	1225.00	20.6	424.36	1.0	1.0	36.0	1296.00	21.6	466.56
	30.1	906.01	21.0	441.00	1.0	1.0	31.1	967.21	22.0	484.00
	28.8	829.44	20.6	424.36	1.5	2.25	30.3	918.09	22.1	488.41
	29.1	846.81	18.4	338.56	1.25	1.5625	30.35	921.1225	19.65	386.1225
	25.5	650.25	17.8	316.84	2.0	4.0	27.5	756.25	19.8	392.04
	28.0	784.00	16.4	268.96	2.5	6.25	30.5	930.25	18.9	357.21
	27.2	739.84	16.4	268.96	2.0	4.0	29.2	852.64	18.4	338.56
	26.2	686.44	16.2	262.44	2.0	4.0	28.2	795.24	18.2	331.24
	28.8	829.44	18.4	338.56	1.25	1.5625	30.05	903.0025	19.65	386.1225
675	30.7	942.49	19.1	364.81	2.25	5.0625	32.95	1085.7025	21.35	455.8225
	27.6	761.76	22.7	515.29	2.0	4.0	29.6	876.16	24.7	610.09
	24.5	600.25	20.2	408.04	2.5	6.25	27.0	729.00	22.7	515.29

Subject's number	l	l^2	s	s^2	Time since last meal m	m^2	l + m	$(l + m)^2$	s + m	$(s + m)^2$
675	27.3	745.29	19.6	384.16	2.25	5.0625	29.55	873.2025	21.85	477.4225
	24.2	585.64	16.6	275.56	2.0	4.0	26.2	686.44	18.6	345.96
	28.7	823.69	20.6	424.36	1.25	1.5625	29.95	873.2025	21.85	477.4225
	24.8	615.04	18.9	357.21	2.5	6.25	27.3	745.29	21.4	457.96
	26.8	718.24	19.0	361.00	2.5	6.25	29.3	858.49	21.5	462.25
	21.6	466.56	19.7	388.09	1.25	1.5625	22.85	522.1225	20.95	438.9025
	25.0	625.00	19.8	392.04	1.25	1.5625	26.25	689.0625	21.05	443.1025
	22.0	484.00	19.5	380.25	2.0	4.0	24.0	576.00	21.5	462.25
611	30.8	948.64	14.1	198.81	2.75	7.5625	33.55	1125.6025	16.85	283.9225
	33.3	1108.89	21.2	449.44	2.25	5.0625	35.55	1263.8025	23.45	549.9025
	30.9	954.81	18.4	338.56	1.5	2.25	32.4	1049.76	19.9	396.01
	27.4	750.76	19.9	396.01	1.66	2.7556	29.06	844.4836	21.56	464.8336
	23.1	533.61	17.9	320.41	3.25	10.5625	26.35	694.3225	21.15	447.3225
	25.5	650.25	15.9	252.81	7.0	49.0	32.5	1056.25	22.9	524.41
	21.8	475.24	17.5	306.25	10.0	100.0	31.8	1011.24	27.5	1406.25
	25.2	635.04	18.8	353.44	3.75	14.0625	28.95	838.1025	22.55	508.5025
	25.9	670.81	19.5	380.25	1.5	2.25	27.4	750.76	21.0	441.00

Subject's number	l	l^2	s	s^2	Time since last meal m	m^2	l + m	$(l + m)^2$	s + m	$(s + m)^2$
422	23.7	561.69	16.4	268.96	1.25	1.5625	24.95	622.5025	17.65	311.5225
	21.2	449.44	16.2	262.44	1.5	2.25	22.7	515.29	17.7	313.29
191	26.1	681.21	17.8	316.84	1.5	2.25	27.6	761.76	19.3	372.49
	23.3	542.89	17.2	295.84	1.75	3.0625	25.05	627.5025	18.95	359.1025
	19.9	396.01	17.0	289.00	1.0	1.0	20.9	436.81	18.0	324.00
	21.9	479.61	18.1	327.61	1.0	1.0	22.9	524.41	19.1	364.81
	21.3	453.69	16.5	272.25	2.33	5.4289	23.63	558.3769	18.83	354.5689
355	21.5	462.25	14.8	219.04	2.33	5.4289	23.83	567.8689	17.13	293.4369
	23.0	529.00	15.1	228.01	1.5	2.25	24.5	600.25	16.6	275.56
	25.6	655.36	17.3	299.29	2.0	4.0	27.6	761.76	19.3	372.49
	22.4	501.76	15.4	237.16	2.5	6.25	24.9	620.01	17.9	320.41
	23.6	556.96	19.0	361.00	1.5	2.25	25.1	630.01	20.5	420.25
	23.9	571.21	19.9	396.01	1.5	2.25	25.4	645.16	21.4	457.96
	25.6	655.36	20.1	404.01	1.0	1.0	26.6	707.56	21.1	445.21
	25.8	665.64	17.8	316.84	2.0	4.0	27.8	772.84	19.8	392.04
	25.6	655.36	18.1	327.61	2.25	5.0625	27.85	775.6225	20.35	414.1225
	25.5	650.25	16.9	285.61	1.66	2.7556	27.16	737.6656	18.56	344.4736

Subject's number	l	l^2	s	s^2	Time since last meal m	m^2	$l + m$	$(l + m)^2$	$s + m$	$(s + m)^2$
378	39.9	1592.01	26.1	681.21	2.5	6.25	42.4	1797.76	28.6	817.96
	31.0	961.00	24.2	585.64	1.0	1.0	32.0	1024.00	25.2	635.04
	29.8	888.04	19.2	368.64	2.0	4.0	31.8	1011.24	21.2	449.44
	28.2	795.24	21.9	479.61	1.0	1.0	29.2	852.64	22.9	524.41
	29.1	846.81	24.1	580.81	0.5	0.25	29.6	876.16	24.6	605.16
	27.1	734.41	24.8	615.04	1.0	1.0	28.1	789.61	25.8	665.64
	27.2	739.84	22.2	492.84	2.0	4.0	29.2	852.64	24.2	585.64
	30.3	918.09	23.4	547.56	2.5	6.25	32.8	1075.84	25.9	670.81
	30.8	948.64	24.8	615.04	1.5	2.25	32.3	1043.29	26.3	691.69
103	29.3	858.49	19.8	392.04	1.75	3.0625	31.05	964.1025	21.55	464.4025
	31.0	961.00	20.2	408.04	1.75	3.0625	32.75	1072.5625	21.95	481.8025
	26.9	723.61	21.2	449.44	2.0	4.0	28.9	835.21	23.2	538.24
	26.5	702.25	18.8	353.44	4.0	16.0	30.5	930.25	22.8	519.84
	25.9	670.81	16.3	265.69	1.5	2.25	27.4	750.76	17.8	316.84
	22.0	484.00	17.0	289.00	1.0	1.0	23.0	529.00	18.0	324.00
	23.0	529.00	18.6	345.96	1.5	2.25	24.5	600.25	20.1	404.01

Subject's number	l	l^2	s	s^2	Time since last meal m	m^2	l + m	$(l + m)^2$	s + m	$(s + m)^2$
103	22.5	506.25	19.5	380.25	2.0	4.0	24.5	600.25	21.5	462.25
	23.2	538.24	16.4	268.96	0.75	0.5625	23.95	573.6025	17.15	294.1225
	23.6	556.96	16.2	262.44	0.5	0.25	24.1	580.81	16.7	278.89
	34.1	1162.81	15.3	234.09	1.75	3.0625	35.85	1285.2225	17.05	290.7025
27	29.6	876.16	15.2	231.04	2.0	4.0	31.6	998.56	17.2	295.84
	25.9	670.81	17.5	306.25	4.0	16.0	29.9	894.01	21.5	462.25
	29.3	858.49	17.9	320.41	5.0	25.0	34.3	1176.49	22.9	524.41
	25.2	635.04	18.5	342.25	6.0	36.0	31.2	973.44	24.5	600.25
	34.2	1169.64	18.7	349.69	1.5	2.25	35.7	1274.49	20.2	408.04
	29.6	876.16	17.7	313.29	16.0	256.0	45.6	2079.36	33.7	1135.69
	30.5	930.25	19.2	368.64	16.0	256.0	46.5	2162.25	35.2	1239.04
	29.8	888.04	17.6	309.76	16.0	256.00	45.8	2097.64	33.6	1128.96
	32.0	1024.00	16.8	282.24	1.0	1.0	33.0	1089.00	17.8	316.84
	33.0	1089.00	18.8	353.44	5.5	30.25	38.5	1482.25	24.3	590.49
	36.3	1317.69	18.6	345.96	2.0	4.0	38.3	1466.89	20.6	424.36
243	28.2	795.24	16.8	282.24	1.25	1.5625	29.45	867.3025	18.05	325.8025
	29.3	858.49	15.2	231.04	1.0	1.0	30.3	918.09	16.2	262.44

Subject's number	l	l^2	s	s^2	Time since last meal m	m^2	l + m	$(l + m)^2$	s + m	$(s + m)^2$
243	28.0	784.00	15.2	231.04	1.0	1.0	29.0	841.00	16.2	262.44
	23.9	571.21	15.0	225.00	0.5	0.25	24.4	595.36	15.5	240.25
	22.2	492.84	14.8	219.04	2.0	4.0	24.2	585.64	16.8	282.24
	24.2	585.64	14.5	210.25	1.25	1.5625	25.45	647.7025	15.75	248.0625
	22.2	492.84	15.0	225.00	0.75	0.5625	22.95	526.7025	15.75	248.0625
	22.5	506.25	14.7	216.09	1.25	1.5625	23.75	564.0625	15.95	254.4025
	29.7	882.09	13.3	176.89	4.25	18.0625	33.95	1152.6025	17.55	308.0025
	26.1	681.21	12.2	148.84	4.5	20.25	30.6	936.36	16.7	278.89
	27.7	767.29	12.4	153.76	0.75	0.5625	28.45	809.4025	13.15	172.9225
	29.8	888.04	12.1	146.41	1.5	2.25	31.3	979.69	13.6	184.96
209	29.4	864.36	19.4	376.36	2.0	4.0	31.4	985.96	21.4	457.96
	24.8	615.04	18.8	353.44	1.25	1.5625	26.05	678.6025	20.05	402.0025
	26.6	707.56	17.7	313.29	1.75	3.0625	28.35	803.7225	19.45	378.3025
	28.5	812.25	19.4	376.36	1.0	1.0	29.5	870.25	20.4	416.16
	27.6	761.76	19.6	384.16	1.0	1.0	28.6	817.96	20.6	424.36
	27.0	729.00	20.8	432.64	1.0	1.0	28.0	784.00	21.8	475.24
	31.6	998.56	18.1	327.61	1.5	2.25	33.1	1095.61	19.6	384.16

Subject's number	l	l^2	s	s^2	Time since last meal m	m^2	l + m	$(l + m)^2$	s + m	$(s + m)^2$
209	34.0	1156.00	19.5	380.25	1.0	1.0	35.0	1225.00	20.5	420.25
	25.1	630.01	19.2	368.64	4.0	16.0	29.1	846.81	23.2	538.24
	28.2	795.24	19.6	384.16	1.75	3.0625	29.95	897.0025	21.35	455.8225
529	27.4	750.76	18.5	342.25	1.5	2.25	28.9	835.21	20.0	400.00
	25.8	665.64	14.3	204.49	3.25	10.5625	29.05	843.9025	17.55	308.0025
	20.5	420.25	14.5	210.25	4.0	16.0	24.5	600.25	18.5	342.25
	21.0	441.00	15.0	225.00	2.25	5.0625	23.25	540.5625	17.25	297.5625
	21.9	479.61	15.8	249.64	1.75	3.0625	23.65	559.3225	17.55	308.0025
	20.4	416.16	14.6	213.16	1.75	3.0625	22.15	490.6225	16.35	267.3225
	21.7	470.89	14.4	207.36	2.0	4.0	23.7	561.69	16.4	268.96
	20.4	416.16	14.7	216.09	3.5	12.25	23.9	571.21	18.2	331.24
	19.6	384.16	13.9	193.21	2.5	6.25	22.1	488.41	16.4	268.96
	19.9	396.01	13.6	184.96	1.0	1.0	20.9	436.81	14.6	213.16
	19.0	361.00	14.0	196.00	1.0	1.0	20.0	400.00	15.0	225.00
71	25.3	640.09	17.6	309.76	2.75	7.5625	28.05	786.8025	20.35	414.1225
	26.0	676.00	17.5	306.25	1.5	2.25	27.5	756.25	19.0	361.00
	22.6	510.76	16.1	259.21	1.5	2.25	24.1	580.81	17.6	309.76

Subject's number	l	l^2	s	s^2	Time since last meal m	m^2	l + m	$(l + m)^2$	s + m	$(s + m)^2$
71	26.1	681.21	19.3	372.49	3.0	9.0	29.1	846.81	22.3	497.29
	24.7	610.09	17.1	292.41	1.5	2.25	26.2	686.44	18.6	345.96
	24.7	610.09	17.2	295.84	3.0	9.0	27.7	767.29	20.2	408.04
	22.6	510.76	18.5	342.25	1.75	3.0625	24.35	592.9225	20.25	410.0625
	29.6	876.16	19.3	372.49	1.25	1.5625	30.85	951.7225	20.55	422.3025
	33.7	1135.69	17.0	289.00	1.0	1.0	34.7	1204.09	18.0	324.00
	32.2	1036.84	18.3	334.89	1.75	3.0625	33.95	1152.6025	20.05	402.0025
	32.0	1024.00	17.9	320.41	1.66	2.7556	33.66	1132.9956	19.56	382.5936
524	38.2	1459.24	15.7	246.49	1.5	2.25	39.7	1576.09	17.2	295.84
	37.1	1376.41	12.6	158.76	1.0	1.0	38.1	1451.61	13.6	184.96
	35.2	1239.04	16.0	256.00	1.0	1.0	36.2	1310.44	17.0	289.00
	32.3	1043.29	14.4	207.36	1.0	1.0	33.3	1108.89	15.4	237.16
	31.6	998.56	15.6	243.36	1.0	1.0	32.6	1062.76	16.6	275.56
	30.9	954.81	14.7	216.09	2.0	4.0	32.9	1082.41	16.7	278.89
	32.5	1056.25	14.8	219.04	1.0	1.0	33.5	1122.25	15.8	249.64
	30.2	912.04	12.6	158.76	1.0	1.0	31.2	973.44	13.6	184.96
	34.5	1190.25	19.2	368.64	1.0	1.0	35.5	1260.25	20.2	408.04

Subject's number	l	l^2	s	s^2	Time since last meal m	m^2	l + m	$(l + m)^2$	s + m	$(s + m)^2$
524	34.6	1197.16	16.4	268.96	1.0	1.0	35.6	1267.36	17.4	302.76
	33.7	1135.69	17.8	316.84	1.0	1.0	34.7	1204.09	18.8	353.44
8	30.8	948.64	13.3	176.89	1.25	1.5625	32.05	1027.2025	14.55	211.7025
678	32.2	1036.84	18.0	324.00	1.5	2.25	33.7	1135.69	19.5	380.25
572	35.3	1246.09	17.4	302.76	1.0	1.0	36.3	1317.69	18.4	338.56
683	31.4	985.96	22.6	510.76	1.5	2.25	32.9	1082.41	24.1	580.81
239	33.2	1102.24	24.9	620.01	0.75	0.5625	33.95	1152.6025	25.65	657.9225
250	33.1	1095.61	14.8	219.04	1.0	1.0	34.1	1162.81	15.8	249.64
359	29.7	882.09	16.3	265.69	2.0	4.0	31.7	1004.89	18.3	334.89
526	32.5	1056.25	20.4	416.16	1.5	2.25	34.0	1156.00	21.9	479.61
24	37.4	1398.76	18.8	353.44	1.66	2.7556	39.06	1525.6836	20.46	418.6116
342	34.7	1204.09	19.4	376.36	1.25	1.5625	35.95	1292.4025	20.65	426.4225
156	28.2	795.24	17.6	309.76	0.75	0.5625	28.95	838.1025	18.35	336.7225
130	29.5	870.25	14.8	219.04	1.0	1.0	30.5	930.25	15.8	249.64
527	33.3	1108.89	20.5	420.25	2.75	7.5625	36.05	1299.6025	23.25	540.5625
680	38.8	1505.44	22.5	506.25	1.25	1.5625	40.05	1604.0025	23.75	564.0625
556	26.1	681.21	19.1	364.81	1.5	2.25	27.6	761.76	20.6	424.36

Subject's number	l	l^2	s	s^2	Time since last meal m	m^2	$l + m$	$(l + m)^2$	$s + m$	$(s + m)^2$
54	29.7	882.09	21.0	441.00	1.0	1.0	30.7	942.49	22.0	484.00
310	32.2	1036.84	18.1	327.61	2.0	4.0	34.2	1169.64	20.1	404.01
146	33.0	1089.00	18.4	338.56	1.0	1.0	34.0	1156.00	19.4	376.36
268	25.8	665.64	19.8	392.04	1.25	1.5625	27.05	731.7025	21.05	443.1025
213	33.6	1128.96	28.3	800.89	2.0	4.0	35.6	1267.36	30.3	918.09
483	28.2	795.24	18.0	324.00	1.0	1.0	29.2	852.64	19.0	361.00
681	32.8	1075.84	20.7	428.49	1.5	2.25	34.3	1176.49	22.2	492.84
374	27.4	750.76	17.6	309.76	2.25	5.0625	29.65	879.1225	19.85	394.0225
682	24.7	610.09	17.4	302.76	2.5	6.25	27.2	739.84	19.9	396.01
557	23.2	538.24	17.0	289.00	1.0	1.0	24.2	585.64	18.0	324.00
543	33.9	1149.21	23.8	566.44	0.75	0.5625	34.65	1200.6225	24.55	602.7025
117	30.0	900.00	21.6	466.56	1.5	2.25	31.5	992.25	23.1	533.61
604	26.5	702.25	19.2	368.64	1.75	3.0625	28.25	798.0625	20.95	438.9025
418	32.2	1036.84	18.2	331.24	1.5	2.25	33.7	1135.69	19.7	388.09
202	33.0	1089.00	18.2	331.24	1.33	1.7689	34.33	1178.5489	19.53	381.4209
262	32.9	1082.41	20.0	400.00	2.5	6.25	35.4	1253.16	22.5	506.25
539	30.4	924.16	19.0	361.00	1.5	2.25	31.9	1017.61	20.5	420.25

Subject's number	l	l^2	s	s^2	Time since last meal m	m^2	l + m	$(l + m)^2$	s + m	$(s + m)^2$
608	28.0	784.00	15.0	225.00	2.0	4.0	30.0	900.00	17.0	289.00
528	31.4	985.96	18.4	338.56	2.33	5.4289	33.73	1137.7129	20.73	429.7329
162	25.1	630.01	18.0	324.00	2.5	6.25	27.6	761.76	20.5	420.25
216	30.4	924.16	18.2	331.24	1.5	2.25	31.9	1017.61	19.7	388.09
107	30.8	948.64	23.2	538.24	2.0	4.0	32.8	1075.84	25.2	635.04
534	23.0	529.00	18.8	353.44	0.5	0.25	23.5	552.25	19.3	372.49
368	22.9	524.41	17.0	289.00	1.5	2.25	24.4	595.36	18.5	342.25
TOTAL 242	6754.7	192529.44	4465.7	84093.95	478.22	1982.3450	7234.00	222948.7150	4943.90	102211.7028
MEAN	27.91	795.58	18.45	347.49	1.97	8.1915	29.89	913.0110	20.43	422.3621

T A B L E xix.

EFFECT OF PRACTICE.

Table xix Effect of Practice.

Subject's number	1	1^2	s	s^2	Numerical order of reading (n)	n^2	1 + n	$(1 + n)^2$	s + n	$(s + n)^2$
1000	32.3	1043.29	19.0	361.00	1	1	33.3	1108.89	20.0	400.00
	26.2	686.44	14.7	216.09	2	4	28.2	795.24	16.7	278.89
	27.6	761.76	15.7	246.49	3	9	30.6	936.36	18.7	349.69
	26.2	686.44	16.5	272.25	4	16	30.2	912.04	20.5	420.25
	23.5	552.25	16.9	285.61	5	25	28.5	812.25	21.9	479.61
	23.5	552.25	14.8	219.04	6	36	29.5	870.25	20.8	432.64
	25.3	640.09	15.8	249.64	7	49	32.3	1043.29	22.8	519.84
	25.7	660.49	16.3	265.69	8	64	33.7	1135.69	24.3	590.49
	30.8	948.64	15.7	246.49	9	81	39.8	1584.04	24.7	610.09
	26.5	702.25	17.0	289.00	10	100	36.5	1332.25	27.0	729.00
230	32.0	1024.00	17.4	302.76	1	1	33.0	1089.00	18.4	338.56
	27.8	772.84	19.3	372.49	2	4	29.8	888.04	21.3	453.69
	27.1	734.41	20.3	412.09	3	9	30.1	906.01	23.3	542.89
	25.8	665.64	17.1	292.41	4	16	29.8	888.04	21.1	445.21
	27.4	750.76	19.8	392.04	5	25	32.4	1049.76	24.8	615.04
	28.3	800.89	19.4	376.36	6	36	34.3	1176.49	25.4	645.16

Subject's number	1	1^2	s	s^2	Numerical order of reading (n)	n^2	1 + n	$(1 + n)^2$	s + n	$(s + n)^2$
230	26.8	718.24	19.3	372.49	7	49	33.8	1142.44	26.3	691.69
	29.1	846.81	21.9	479.61	8	64	37.1	1376.41	29.9	894.01
	22.5	506.25	15.4	237.16	9	81	31.5	992.25	24.4	595.36
1006	29.3	858.49	19.1	364.81	1	1	30.3	918.09	20.1	404.01
	29.7	882.09	18.0	324.00	2	4	31.7	1004.89	20.0	400.00
	27.0	729.00	16.3	265.69	3	9	30.0	900.00	19.3	372.49
	24.6	605.16	17.2	295.84	4	16	28.6	817.96	21.2	449.44
	26.7	712.89	18.5	342.25	5	25	31.7	1004.89	23.5	552.25
	24.6	605.16	16.0	256.00	6	36	30.6	936.36	22.0	484.00
	20.4	416.16	14.1	198.81	7	49	27.4	750.76	21.1	445.21
	19.3	372.49	15.2	231.04	8	64	27.3	745.29	23.2	538.24
	22.1	488.41	17.4	302.76	9	81	31.1	967.21	26.4	696.96
	25.2	635.04	17.8	316.84	10	100	35.2	1239.04	27.8	772.84
	23.6	556.96	19.7	388.09	11	121	34.6	1197.16	30.7	942.49
	22.0	484.00	16.5	272.25	12	144	34.0	1156.00	28.5	812.25
20	29.3	858.49	19.7	388.09	1	1	30.3	918.09	20.7	428.49
	28.6	817.96	20.6	424.36	2	4	30.6	936.36	22.6	510.76

Subject's number	l	l^2	s	s^2	Numerical order of reading (n)	n^2	l + n	$(l + n)^2$	s + n	$(s + n)^2$
20	27.7	767.29	21.2	449.44	3	9	30.7	942.49	24.2	585.64
	30.1	906.01	23.4	547.56	4	16	34.1	1162.81	27.4	750.76
	28.9	835.21	22.9	524.41	5	25	33.9	1149.21	27.9	778.41
	32.2	1036.84	22.8	519.84	6	36	38.2	1459.24	28.8	829.44
	27.9	778.41	21.8	475.24	7	49	34.9	1218.01	28.8	829.44
	26.6	707.56	19.6	384.16	8	64	34.6	1197.16	27.6	761.76
	26.2	686.44	19.9	396.01	9	81	35.2	1239.04	28.9	835.21
	29.2	852.64	20.9	436.81	10	100	39.2	1536.64	30.9	954.81
	28.5	812.25	20.2	408.04	11	121	39.5	1560.25	31.2	973.44
531	30.8	948.64	19.9	396.01	1	1	31.8	1011.24	20.9	436.81
	31.5	992.25	19.8	392.04	2	4	33.5	1122.25	21.8	475.24
	30.7	942.49	22.9	524.41	3	9	33.7	1135.69	25.9	670.81
	30.5	930.25	21.6	466.56	4	16	34.5	1190.25	25.6	655.36
	29.0	841.00	18.7	349.69	5	25	34.0	1156.00	23.7	561.69
	30.7	942.49	21.2	449.44	6	36	36.7	1346.89	27.2	739.84
	30.4	924.16	19.6	384.16	7	49	37.4	1398.76	26.6	707.56
	28.3	800.89	20.4	416.16	8	64	36.3	1317.69	28.4	806.56

Subject's number	1	1^2	s	s^2	Numerical order of reading (n)	n^2	1 + n	$(1 + n)^2$	s + n	$(s + n)^2$
531	29.7	882.09	18.3	334.89	9	81	38.7	1497.69	27.3	745.29
	27.8	772.84	17.1	292.41	10	100	37.8	1428.84	27.1	734.41
	32.0	1024.00	19.7	388.09	11	121	43.0	1849.00	30.7	942.49
280	27.8	772.84	16.3	265.69	1	1	28.8	829.44	17.3	299.29
	24.8	615.04	17.3	299.29	2	4	26.8	718.24	19.3	372.49
	25.3	640.09	18.4	338.56	3	9	28.3	800.89	21.4	457.96
	27.3	745.29	19.3	372.49	4	16	31.3	979.69	23.3	542.89
	26.0	676.00	18.0	324.00	5	25	31.0	961.00	23.0	529.00
	23.9	571.21	17.8	316.84	6	36	29.9	894.01	23.8	566.44
	26.8	718.24	18.2	331.24	7	49	33.8	1142.44	25.2	635.04
	26.4	696.96	17.1	292.41	8	64	34.4	1183.36	25.1	630.01
	24.3	590.49	18.2	331.24	9	81	33.3	1108.89	27.2	739.84
	27.5	756.25	17.2	295.84	10	100	37.5	1406.25	27.2	739.84
	25.6	655.36	17.0	289.00	11	121	36.6	1339.56	28.0	784.00
221	32.7	1069.29	19.1	364.81	1	1	33.7	1135.69	20.1	404.01
	27.3	745.29	19.0	361.00	2	4	29.3	858.49	21.0	441.00
	28.8	829.44	21.9	479.61	3	9	31.8	1011.24	24.9	620.01

Subject's number	l	l^2	s	s^2	Numerical order of reading (n)	n^2	l + n	$(l + n)^2$	s + n	$(s + n)^2$
221	30.1	906.01	21.2	449.44	4	16	34.1	1162.81	25.2	635.04
	31.1	967.21	22.0	484.00	5	25	36.1	1303.21	27.0	729.00
	30.2	912.04	23.0	529.00	6	36	36.2	1310.44	29.0	841.00
	28.2	795.24	20.4	416.16	7	49	35.2	1239.04	27.4	750.76
	26.2	686.44	18.3	334.89	8	64	34.2	1169.64	26.3	691.69
	29.2	852.64	20.7	428.49	9	81	38.2	1459.24	29.7	882.09
	30.3	918.09	21.3	453.69	10	100	40.3	1624.09	31.3	979.69
	29.2	852.64	19.4	376.36	11	121	40.2	1616.04	30.4	924.16
530	30.3	918.09	17.9	320.41	1	1	31.3	979.69	18.9	357.21
	25.0	625.00	19.6	384.16	2	4	27.0	729.00	21.6	466.56
	27.6	761.76	20.3	412.09	3	9	30.6	936.36	23.3	542.89
	24.6	605.16	18.9	357.21	4	16	28.6	817.96	22.9	524.41
	25.7	660.49	17.5	306.25	5	25	30.7	942.49	22.5	506.25
	24.4	595.36	17.6	309.76	6	36	30.4	924.16	23.6	556.96
	21.6	466.56	16.7	278.89	7	49	28.6	817.96	23.7	561.69
	22.6	510.76	19.3	372.49	8	64	30.6	936.36	27.3	745.29
	26.4	696.96	17.6	309.76	9	81	35.4	1253.16	26.6	707.56

Subject's number	l	l^2	s	s^2	Numerical order of reading (n)	n^2	l + n	$(l + n)^2$	s + n	$(s + n)^2$
447	35.0	1225.00	20.6	424.36	1	1	36.0	1296.00	21.6	466.56
	30.1	906.01	21.0	441.00	2	4	32.1	1030.41	23.0	529.00
	28.8	829.44	20.6	424.36	3	9	31.8	1011.24	23.6	556.96
	29.1	846.81	18.4	338.56	4	16	33.1	1095.61	22.4	501.76
	25.5	650.25	17.8	316.84	5	25	30.5	930.25	22.8	519.84
	28.0	784.00	16.4	268.96	6	36	34.0	1156.00	22.4	501.76
	27.2	739.84	16.4	268.96	7	49	34.2	1169.64	23.4	547.56
	26.2	686.44	16.2	262.44	8	64	34.2	1169.64	24.2	585.64
	28.8	829.44	18.4	338.56	9	81	37.8	1428.84	27.4	750.76
675	30.7	942.49	19.1	364.81	1	1	31.7	1004.89	20.1	404.01
	27.6	761.76	22.7	515.29	2	4	29.6	876.16	24.7	610.09
	24.5	600.25	20.2	408.04	3	9	27.5	756.25	23.2	538.24
	27.3	745.29	19.6	384.16	4	16	31.3	979.69	23.6	556.96
	24.2	585.64	16.6	275.56	5	25	29.2	852.64	21.6	466.56
	28.7	823.69	20.6	424.36	6	36	34.7	1204.09	26.6	707.56
	24.8	615.04	18.9	357.21	7	49	31.8	1011.24	25.9	670.81
	26.8	718.24	19.0	361.00	8	64	34.8	1211.04	27.0	729.00

Subject's number	l	l^2	s	s^2	Numerical order of reading (n)	n^2	l + n	$(l + n)^2$	s + n	$(s + n)^2$
675	21.6	466.56	19.7	388.09	9	81	30.6	936.36	28.7	823.69
	25.0	625.00	19.8	392.04	10	100	35.0	1225.00	29.8	888.04
	22.0	484.00	19.5	380.25	11	121	33.0	1089.00	30.5	930.25
611	30.8	948.64	14.1	198.81	1	1	31.8	1011.24	15.1	228.01
	33.3	1108.89	21.2	449.44	2	4	35.3	1246.09	23.2	538.24
	30.9	954.81	18.4	338.56	3	9	33.9	1149.21	21.4	457.96
	27.4	750.76	19.9	396.01	4	16	31.4	985.96	23.9	571.21
	23.1	533.61	17.9	320.41	5	25	28.1	789.61	22.9	524.41
	25.5	650.25	15.9	252.81	6	36	31.5	992.25	21.9	479.61
	21.8	475.24	17.5	306.25	7	49	28.8	829.44	24.5	600.25
	25.2	635.04	18.8	353.44	8	64	33.2	1102.24	26.8	718.24
	25.9	670.81	19.5	380.25	9	81	34.9	1218.01	28.5	812.25
520	33.2	1102.24	21.7	470.89	1	1	34.2	1169.64	22.7	515.29
	29.9	894.01	18.8	353.44	2	4	31.9	1017.61	20.8	432.64
	30.3	918.09	20.5	420.25	3	9	33.3	1108.89	23.5	552.25
	24.5	600.25	19.4	376.36	4	16	28.5	812.25	23.4	547.56
	26.2	686.44	20.8	432.64	5	25	31.2	973.44	25.8	665.64

Subject's number	1	1^2	s	s^2	Numerical order of reading (n)	n^2	1 + n	$(1 + n)^2$	s + n	$(s + n)^2$
520	26.9	723.61	19.1	364.81	6	36	32.9	1082.41	25.1	630.01
	24.1	580.81	18.1	327.61	7	49	31.1	967.21	25.1	630.01
	30.5	930.25	21.2	449.44	8	64	38.5	1482.25	29.2	852.64
	29.2	852.64	19.6	384.16	9	81	38.2	1459.24	28.6	817.96
	31.0	961.00	20.6	424.36	10	100	41.0	1681.00	30.6	936.36
422	30.3	918.09	18.9	357.21	1	1	31.3	979.69	19.9	396.01
	21.1	445.21	16.8	282.24	2	4	23.1	533.61	18.8	353.44
	26.3	691.69	18.0	324.00	3	9	29.3	858.49	21.0	441.00
	33.6	1128.96	21.2	449.44	4	16	37.6	1413.76	25.2	635.04
	24.9	620.01	20.4	416.16	5	25	29.9	894.01	25.4	645.16
	26.6	707.56	15.5	240.25	6	36	32.6	1062.76	21.5	462.25
	31.9	1017.61	18.8	353.44	7	49	38.9	1513.21	25.8	665.64
	23.0	529.00	15.2	231.04	8	64	31.0	961.00	23.2	538.24
	23.7	561.69	16.4	268.96	9	81	32.7	1069.29	25.4	645.16
	21.2	449.44	16.2	262.44	10	100	31.2	973.44	26.2	686.44
191	26.1	681.21	17.8	316.84	1	1	27.1	734.41	18.8	353.44
	24.2	585.64	17.8	316.84	2	4	26.2	585.64	19.8	392.04

Subject's number	1	1^2	s	s^2	Numerical order of reading (n)	n^2	1 + n	$(1 + n)^2$	s + n	$(s + n)^2$
191	23.3	542.89	17.2	295.84	3	9	26.3	691.69	20.2	408.04
	19.9	396.01	17.0	289.00	4	16	23.9	571.21	21.0	441.00
	21.9	479.61	18.1	327.61	5	25	26.9	723.61	23.1	533.61
	21.3	453.69	16.5	272.25	6	36	27.3	745.29	22.5	506.25
355	21.5	462.25	14.8	219.04	1	1	22.5	506.25	15.8	249.64
	23.0	529.00	15.1	228.01	2	4	25.0	625.00	17.1	292.41
	25.6	655.36	17.3	299.29	3	9	28.6	817.96	20.3	412.09
	22.4	501.76	15.4	237.16	4	16	26.4	696.96	19.4	376.36
	23.6	556.96	19.0	361.00	5	25	28.6	817.96	24.0	576.00
	23.9	571.21	19.9	396.01	6	36	29.9	894.01	25.9	670.81
	25.6	655.36	20.1	404.01	7	49	32.6	1062.76	27.1	734.41
	25.8	665.64	17.8	316.84	8	64	33.8	1142.44	25.8	665.64
	25.6	655.36	18.1	327.61	9	81	34.6	1197.16	27.1	734.41
	25.5	650.25	16.9	285.61	10	100	35.5	1260.25	26.9	723.61
378	39.9	1592.01	26.1	681.21	1	1	40.9	1672.81	27.1	734.41
	31.0	961.00	24.2	585.64	2	4	33.0	1089.00	26.2	686.44
	29.8	888.04	19.2	368.64	3	9	32.8	1075.84	22.2	492.84

Subject's number	l	l^2	s	s^2	Numerical order of reading (n)	n^2	l + n	$(l + n)^2$	s + n	$(s + n)^2$
378	28.2	795.24	21.9	479.61	4	16	32.2	1036.84	25.9	670.81
	29.1	846.81	24.1	580.81	5	25	34.1	1162.81	29.1	846.81
	27.1	734.41	24.8	615.04	6	36	33.1	1095.61	30.8	948.64
	27.2	739.84	22.2	492.84	7	49	34.2	1169.64	29.2	852.64
	30.3	918.09	23.4	547.56	8	64	38.3	1466.89	31.4	985.96
	30.8	948.64	24.8	615.04	9	81	39.8	1584.04	33.8	1142.44
103	29.3	858.49	19.8	392.04	1	1	30.3	918.09	20.8	432.64
	31.0	961.00	20.2	408.04	2	4	33.0	1089.00	22.2	492.84
	26.9	723.61	21.2	449.44	3	9	29.9	894.01	24.2	585.64
	26.5	702.25	18.8	353.44	4	16	30.5	930.25	22.8	519.84
	25.9	670.81	16.3	265.69	5	25	30.9	954.81	21.3	453.69
	22.0	484.00	17.0	289.00	6	36	28.0	784.00	23.0	529.00
	23.0	529.00	18.6	345.96	7	49	30.0	900.00	25.6	655.36
	22.5	506.25	19.5	380.25	8	64	30.5	930.25	27.5	756.25
	23.2	538.24	16.4	268.96	9	81	32.2	1036.84	25.4	645.16
	23.6	556.96	16.6	275.56	10	100	33.6	1128.96	26.6	707.56
	34.1	1162.81	15.3	234.09	11	121	45.1	2034.01	26.3	691.69

Subject's number	l	l^2	s	s^2	Numerical order of reading (n)	n^2	l + n	$(l + n)^2$	s + n	$(s + n)^2$
27	29.6	876.16	15.2	231.04	1	1	30.6	936.36	16.2	262.44
	25.9	670.81	17.5	306.25	2	4	27.9	778.41	19.5	380.25
	29.3	858.49	17.9	320.41	3	9	32.3	1043.29	20.9	436.81
	25.2	635.04	18.5	342.25	4	16	29.2	852.64	22.5	506.25
	34.2	1169.64	18.7	349.69	5	25	39.2	1536.64	23.7	561.69
	29.6	876.16	17.7	313.29	6	36	35.6	1267.36	23.7	561.69
	30.5	930.25	19.2	368.64	7	49	37.5	1406.25	26.2	686.44
	29.8	888.04	17.6	309.76	8	64	37.8	1428.84	25.6	655.36
	32.0	1024.00	16.8	282.24	9	81	41.0	1681.00	25.8	665.64
	33.0	1089.00	18.8	353.44	10	100	43.0	1849.00	28.8	829.44
	36.3	1317.69	18.6	345.96	11	121	47.3	2237.29	29.6	876.16
243	28.2	795.24	16.8	282.24	1	1	29.2	852.64	17.8	316.84
	29.3	858.49	15.2	231.04	2	4	31.3	979.69	17.2	295.84
	28.0	784.00	15.2	231.04	3	9	31.0	961.00	18.2	331.24
	23.9	571.21	15.0	225.00	4	16	27.9	778.41	19.0	361.00
	22.2	492.84	14.8	219.04	5	25	27.2	739.84	19.8	392.04
	24.2	585.64	14.5	210.25	6	36	30.2	912.04	20.5	420.25

Subject's number	l	l^2	s	s^2	Numerical order of reading (n)	n^2	l + n	$(l + n)^2$	s + n	$(s + n)^2$
529	25.8	665.64	14.3	204.49	2	4	27.8	772.84	16.3	265.69
	20.5	420.25	14.5	210.25	3	9	23.5	552.25	17.5	306.25
	21.0	441.00	15.0	225.00	4	16	25.0	625.00	19.0	361.00
	21.9	479.61	15.8	249.64	5	25	26.9	723.61	20.8	432.64
	20.4	416.16	14.6	213.16	6	36	26.4	696.96	20.6	424.36
	21.7	470.89	14.4	207.36	7	49	28.7	823.69	21.4	457.96
	20.4	416.16	14.7	216.09	8	64	28.4	806.56	22.7	515.29
	19.6	384.16	13.9	193.21	9	81	28.6	817.96	22.9	524.41
	19.9	396.01	13.6	184.96	10	100	29.9	894.01	23.6	556.96
	19.0	361.00	14.0	196.00	11	121	30.0	900.00	25.0	625.00
71	25.3	640.09	17.6	309.76	1	1	26.3	691.69	18.6	345.96
	26.0	676.00	17.5	306.25	2	4	28.0	784.00	19.5	380.25
	22.6	510.76	16.1	259.21	3	9	25.6	655.36	19.1	364.81
	26.1	681.21	19.3	372.49	4	16	30.1	906.01	23.3	542.89
	24.7	610.09	17.1	292.41	5	25	29.7	882.09	22.1	488.41
	24.7	610.09	17.2	295.84	6	36	30.7	942.49	23.2	538.24
	22.6	510.76	18.5	342.25	7	49	29.6	876.16	25.5	650.25

Subject's number	l	l^2	s	s^2	Numerical order of reading (n)	n^2	l + n	$(l + n)^2$	s + n	$(s + n)^2$
71	29.6	876.16	19.3	372.49	8	64	37.6	1413.76	27.3	745.29
	33.7	1135.69	17.0	289.00	9	81	42.7	1823.29	26.0	676.00
	32.2	1036.84	18.3	334.89	10	100	42.2	1780.84	28.3	800.89
	32.0	1024.00	17.9	320.41	11	121	43.0	1849.00	28.9	835.21
524	38.2	1459.24	15.7	246.49	1	1	39.2	1536.64	16.7	278.89
	37.1	1376.41	12.6	158.76	2	4	39.1	1528.81	14.6	213.16
	35.2	1239.04	16.0	256.00	3	9	38.2	1459.24	19.0	361.00
	32.3	1043.29	14.4	207.36	4	16	36.3	1317.69	18.4	338.56
	31.6	998.56	15.6	243.36	5	25	36.6	1339.56	20.6	424.36
	30.9	954.81	14.7	216.09	6	36	36.9	1361.61	20.7	428.49
	32.5	1056.25	14.8	219.04	7	49	39.5	1560.25	21.8	475.24
	30.2	912.04	12.6	158.76	8	64	38.2	1459.24	20.6	424.36
	34.5	1190.25	19.2	368.64	9	81	43.5	1892.25	28.2	795.24
	34.6	1197.16	16.4	268.96	10	100	44.6	1989.16	26.4	696.96
	33.7	1135.69	17.8	316.84	11	121	44.7	1998.09	28.8	829.44
552	23.6	556.96	17.0	289.00	1	1	24.6	605.16	18.0	324.00
	25.6	655.36	16.5	272.25	2	4	27.6	761.76	18.5	342.25

Subject's number	l	l^2	s	s^2	Numerical order of reading (n)	n^2	l + n	$(l + n)^2$	s + n	$(s + n)^2$
552	22.4	501.76	16.8	282.24	3	9	25.4	645.16	19.8	392.04
	23.4	547.56	16.2	262.44	4	16	27.4	750.76	20.2	408.04
	25.0	625.00	16.4	268.96	5	25	30.0	900.00	21.4	457.96
	24.0	576.00	15.4	237.16	6	36	30.0	900.00	21.4	457.96
	23.2	538.24	17.6	309.76	7	49	30.2	912.04	24.6	605.16
	23.6	556.96	16.2	262.44	8	64	31.6	998.56	24.2	585.64
	24.0	576.00	17.4	302.76	9	81	33.0	1089.00	26.4	696.96
	23.6	556.96	17.0	289.00	10	100	33.6	1128.96	27.0	729.00
426	34.6	1197.16	16.2	262.44	1	1	35.6	1267.36	17.2	295.84
	33.2	1102.24	18.7	349.69	2	4	35.2	1239.04	20.7	428.49
	28.8	829.44	17.4	302.76	3	9	31.8	1011.24	20.4	416.16
	28.1	789.61	16.0	256.00	4	16	32.1	1030.41	20.0	400.00
	29.1	846.81	16.6	275.56	5	25	34.1	1162.81	21.6	466.56
	24.5	600.25	15.4	237.16	6	36	30.5	930.25	21.4	457.96
	24.4	595.36	18.2	331.24	7	49	31.4	985.96	25.2	635.04
	23.5	552.25	16.2	262.44	8	64	31.5	992.25	24.2	585.64
	24.0	576.00	15.6	243.36	9	81	33.0	1089.00	24.6	605.16

Subject's number	1	1^2	s	s^2	Numerical order of reading (n)	n^2	1 + n	$(1 + n)^2$	s + n	$(s + n)^2$
426	21.4	457.96	15.3	234.09	10	100	31.4	985.96	25.3	640.09
360	29.5	870.25	20.0	400.00	1	1	30.5	930.25	21.0	441.00
	29.1	846.81	18.4	338.56	2	4	31.1	967.21	20.4	416.16
	27.9	778.41	20.0	400.00	3	9	30.9	954.84	23.0	529.00
	28.3	800.89	18.5	342.25	4	16	32.3	1043.29	22.5	506.25
	31.9	1017.61	20.8	432.64	5	25	36.9	1361.61	25.8	665.64
	30.8	948.64	20.7	428.49	6	36	36.8	1354.24	26.7	712.89
	29.0	841.00	21.3	453.69	7	49	36.0	1296.00	28.3	800.89
	30.2	912.04	21.8	475.24	8	64	38.2	1459.24	29.8	888.04
	33.1	1095.61	25.0	625.00	9	81	42.1	1772.41	34.0	1156.00
	34.0	1156.00	20.6	424.36	10	100	44.0	1936.00	30.6	936.36
660	26.6	707.56	16.2	262.44	1	1	27.6	761.76	17.2	295.84
	25.4	645.16	14.8	219.04	2	4	27.4	750.76	16.8	282.24
	25.3	640.09	18.2	331.24	3	9	28.3	800.89	21.2	449.44
	24.8	615.04	16.1	259.21	4	16	28.8	829.44	20.1	404.01
	21.8	475.24	15.7	246.49	5	25	26.8	718.24	20.7	428.49
	27.8	772.84	20.0	400.00	6	36	33.8	1142.44	26.0	676.00

Subject's number	1	1^2	s	s^2	Numerical order of reading (n)	n^2	1 + n	$(1 + n)^2$	s + n	$(s + n)^2$
660	24.8	615.04	18.3	334.89	7	49	31.8	1011.24	25.3	640.09
	21.8	475.24	16.9	285.61	8	64	29.8	888.04	24.9	620.01
	22.1	488.41	15.9	252.81	9	81	31.1	967.21	24.9	620.01
	22.7	515.29	16.6	275.56	10	100	32.7	1069.29	26.6	707.56
607	31.0	961.00	19.0	361.00	1	1	32.0	1024.00	20.0	400.00
	28.3	800.89	16.9	285.61	2	4	30.3	918.09	18.9	357.21
	29.1	846.81	19.6	384.16	3	9	32.1	1030.41	22.6	510.76
	30.1	906.01	24.9	620.01	4	16	34.1	1162.81	28.9	835.21
	27.2	739.84	17.9	320.41	5	25	32.2	1036.84	22.9	524.41
	27.4	750.76	18.1	327.61	6	36	33.4	1115.56	24.1	580.81
	28.0	784.00	23.9	571.21	7	49	35.0	1225.00	30.9	954.81
	27.2	739.84	18.3	334.89	8	64	35.2	1239.04	26.3	691.69
1001	28.3	800.89	16.3	265.69	1	1	29.3	858.49	17.3	299.29
	23.4	547.56	15.2	231.04	2	4	25.4	645.16	17.2	295.84
	24.8	615.04	16.8	282.24	3	9	27.8	772.84	19.8	392.04
	24.0	576.00	17.2	295.84	4	16	28.0	784.00	21.2	449.44
	23.7	561.69	14.9	222.01	5	25	28.7	823.69	19.9	396.01

Subject's number	l	l^2	s	s^2	Numerical order of reading (n)	n^2	l + n	$(l + n)^2$	s + n	$(s + n)^2$
1001	24.6	605.16	14.9	222.01	6	36	30.6	936.36	20.9	436.81
	24.7	610.09	16.8	282.24	7	49	31.7	1004.89	23.8	566.44
	23.0	529.00	15.5	240.25	8	64	31.0	961.00	23.5	552.25
1002	34.7	1204.09	22.2	492.84	1	1	35.7	1274.49	23.2	538.24
	37.7	1421.29	30.4	924.16	2	4	39.7	1576.09	32.4	1049.76
	31.8	1011.24	25.8	665.64	3	9	34.8	1211.04	28.8	829.44
	34.5	1190.25	21.6	466.56	4	16	38.5	1482.25	25.6	655.36
	32.1	1030.41	20.6	424.36	5	25	37.1	1376.41	25.6	655.36
	28.6	817.96	19.4	376.36	6	36	34.6	1197.16	25.4	645.16
	30.6	936.36	20.2	408.04	7	49	37.6	1413.76	27.2	739.84
	27.2	739.84	20.6	424.36	8	64	35.2	1239.04	28.6	817.96
547	27.7	767.29	18.4	338.56	1	1	28.7	823.69	19.4	376.36
	27.0	729.00	20.5	420.25	2	4	29.0	841.00	22.5	506.25
	27.9	778.41	21.6	466.56	3	9	30.9	954.81	24.6	605.16
	30.8	948.64	20.7	428.49	4	16	34.8	1211.04	24.7	610.09
	32.9	1082.41	24.0	576.00	5	25	37.9	1436.41	29.0	841.00
	29.6	876.16	20.0	400.00	6	36	35.6	1267.36	26.0	676.00

Subject's number	l	l^2	s	s^2	Numerical order of reading (n)	n^2	l + n	$(l + n)^2$	s + n	$(s + n)^2$
547	29.6	876.16	20.2	408.04	7	49	36.6	1339.56	27.2	739.84
	30.3	918.09	21.6	466.56	8	64	38.3	1466.89	29.6	876.16
500	34.0	1156.00	19.9	396.01	1	1	35.0	1225.00	20.9	436.81
	34.2	1169.64	19.2	368.64	2	4	36.2	1310.44	21.2	449.44
	29.8	888.04	17.5	306.25	3	9	32.8	1075.84	20.5	420.25
	32.2	1036.84	17.4	302.76	4	16	36.2	1310.44	21.4	457.96
	30.2	912.04	18.9	357.21	5	25	35.2	1239.04	23.9	571.21
	29.7	882.09	21.2	449.44	6	36	35.7	1274.49	27.2	739.84
	29.9	894.01	18.8	353.44	7	49	36.9	1361.61	25.8	665.64
	29.0	841.00	19.6	384.16	8	64	37.0	1369.00	27.6	761.76
	26.7	712.89	20.4	416.16	9	81	35.7	1274.49	29.4	864.36
	30.5	930.25	26.3	691.69	10	100	40.5	1640.25	36.3	1317.69
186	27.4	750.76	20.6	424.36	1	1	28.4	806.56	21.6	466.56
	30.1	906.01	19.6	384.16	2	4	32.1	1030.41	21.6	466.56
	27.4	750.76	19.0	361.00	3	9	30.4	924.16	22.0	484.00
	29.6	876.16	25.6	655.36	4	16	33.6	1128.96	29.6	876.16
	28.7	823.69	22.9	524.41	5	25	33.7	1135.69	27.9	778.41

Subject's number	l	l^2	s	s^2	Numerical order of reading (n)	n^2	l + n	$(l + n)^2$	s + n	$(s + n)^2$
19	29.9	894.01	20.9	436.81	3	9	32.9	1082.41	23.9	571.21
	33.1	1095.61	27.0	729.00	4	16	37.1	1376.41	31.0	961.00
	29.7	882.09	22.4	501.76	5	25	34.7	1204.09	27.4	750.76
	33.4	1115.56	24.6	605.16	6	36	39.4	1552.36	30.6	936.36
	33.0	1089.00	25.3	640.09	7	49	40.0	1600.00	32.3	1043.29
	35.8	1281.64	25.2	635.04	8	64	43.8	1918.44	33.2	1102.24
69	34.5	1190.25	19.8	392.04	1	1	35.5	1260.25	20.8	432.64
	35.5	1260.25	20.0	400.00	2	4	37.5	1406.25	22.0	484.00
	33.2	1102.24	20.8	432.64	3	9	36.2	1310.44	23.8	566.44
	34.6	1197.16	19.9	396.01	4	16	38.6	1489.96	23.9	571.21
	35.2	1239.04	21.3	453.69	5	25	40.2	1616.04	26.3	691.69
	35.5	1260.25	19.7	388.09	6	36	41.5	1722.25	25.7	660.49
	34.9	1218.01	21.6	466.56	7	49	41.9	1755.61	28.6	817.96
	36.7	1346.89	20.8	432.64	8	64	44.7	1998.09	28.8	829.44
	34.0	1156.00	20.9	436.81	9	81	43.0	1849.00	29.9	894.01
	36.1	1303.21	22.4	501.76	10	100	46.1	2125.21	32.4	1049.76
308	39.3	1544.49	21.4	457.96	1	1	40.3	1624.09	22.4	501.76

Subject's number	l	l^2	s	s^2	Numerical order of reading (n)	n^2	$l + n$	$(l + n)^2$	$s + n$	$(s + n)^2$
308	36.1	1303.21	19.2	368.64	2	4	38.1	1451.61	21.2	449.44
	33.0	1089.00	19.4	376.36	3	9	36.0	1296.00	22.4	501.76
	36.5	1332.25	20.1	404.01	4	16	40.5	1640.25	24.1	580.81
	33.9	1149.21	19.1	364.81	5	25	38.9	1513.21	24.1	580.81
	37.0	1369.00	19.2	368.64	6	36	43.0	1849.00	25.2	635.04
	34.7	1204.09	18.9	357.21	7	49	41.7	1738.89	25.9	670.81
	37.8	1428.84	20.4	416.16	8	64	45.8	2097.64	28.4	806.56
	38.9	1513.21	21.8	475.24	9	81	47.9	2294.41	30.8	948.64
	39.3	1544.49	23.6	556.96	10	100	49.3	2430.49	33.6	1128.96
212	33.7	1135.69	22.3	497.29	1	1	34.7	1204.09	23.3	542.89
	31.1	967.21	21.5	462.25	2	4	33.1	1095.61	23.5	552.25
	29.0	841.00	20.0	400.00	3	9	32.0	1024.00	23.0	529.00
	31.9	1017.61	22.9	524.41	4	16	35.9	1288.81	26.9	723.61
	28.9	835.21	20.2	408.04	5	25	33.9	1149.21	25.2	635.04
	32.4	1049.76	21.2	449.44	6	36	38.4	1474.56	27.2	739.84
591	42.3	1789.29	25.8	665.64	1	1	43.3	1874.89	26.8	718.24
	32.1	1030.41	23.0	529.00	2	4	34.1	1162.81	25.0	625.00

Subject's number	1	1^2	s	s^2	Numerical order of reading (n)	n^2	1 + n	$(1 + n)^2$	s + n	$(s + n)^2$
591	33.0	1089.00	23.3	542.89	3	9	36.0	1296.00	26.3	691.69
	27.7	767.29	20.2	408.04	4	16	31.7	1004.89	24.2	585.64
	24.0	576.00	17.5	306.25	5	25	29.0	841.00	22.5	506.25
	25.6	655.36	15.8	249.64	6	36	31.6	998.56	21.8	475.24
623	32.1	1030.41	21.5	462.25	1	1	33.1	1095.61	22.5	506.25
	39.9	1592.01	23.3	542.89	2	4	41.9	1755.61	25.3	640.09
	35.2	1239.04	23.7	561.69	3	9	38.2	1459.24	26.7	712.89
	35.6	1267.36	21.7	470.89	4	16	39.6	1568.16	25.7	660.49
	31.0	961.00	23.3	542.89	5	25	36.0	1296.00	28.3	800.89
	31.7	1004.89	19.4	376.36	6	36	37.7	1421.29	25.4	645.16
TOTAL 383	10808.1	311842.32	7172.0	137362.28	2075	1455.9	12883.1	441643.46	9247.0	229419.68
MEAN	28.22	814.21	18.72	358.65	5.42	38.01	33.64	1153.11	24.14	599.02

T A B L E xx.

ALOCHOL READINGS IRRESPECTIVE OF FITNESS OR OTHERWISE TO DRIVE.

Table ~~XX~~ Alcohol Readings.

Subject's number	Age (t)	t^2	R.T. to light (l)	l^2	t + l	$(t + l)^2$	R.T. to sound (s)	s^2	s + t	$(s + t)^2$	s + l	$(s + l)^2$
20	25	625	28.2	795.24	53.2	2830.24	22.2	492.84	47.2	2227.84	50.4	2540.16
	25	625	27.8	772.84	52.8	2787.84	20.6	424.36	45.6	2079.36	48.4	2342.56
	25	625	28.0	784.00	53.0	2809.00	21.3	453.69	46.3	2143.69	49.3	2430.49
	25	625	26.2	686.44	51.2	2621.44	19.8	392.04	44.8	2007.04	46.0	2116.00
	25	625	25.3	640.09	50.3	2530.09	19.9	396.01	44.9	2016.01	45.2	2043.04
531	24	576	33.6	1128.96	57.6	3317.76	19.9	396.01	43.9	1927.21	53.5	2862.25
	24	576	29.6	876.16	53.6	2872.96	20.8	432.64	44.8	2007.04	50.4	2540.16
	24	576	29.9	894.01	53.9	2905.21	19.0	361.00	43.0	1849.00	48.9	2391.21
	24	576	29.6	876.16	53.6	2872.96	21.0	441.00	45.0	2025.00	50.6	2560.36
	24	576	31.8	1011.24	55.8	3113.64	22.0	484.00	46.0	2116.00	53.8	2894.44
280	24	576	26.8	718.24	50.8	2580.64	21.4	457.96	45.4	2061.16	48.2	2323.24
	24	576	25.8	665.64	49.8	2480.04	19.5	380.25	43.5	1892.25	45.3	2052.09
	24	576	26.9	723.61	50.9	2590.81	20.4	416.16	44.4	1971.36	47.3	2237.29
	24	576	26.7	712.89	50.7	2570.49	21.8	475.24	45.8	2097.64	48.5	2352.25
	24	576	24.7	610.09	48.7	2371.69	19.4	376.36	43.4	1883.56	44.1	1944.81
221	25	625	26.9	723.61	51.9	2693.61	20.4	416.16	45.4	2061.16	47.3	2237.29

Subject's number	Age (t)	t^2	R.T. to light (l)	l^2	$t + l$	$(t + l)^2$	R.T. to sound (s)	s^2	$s + t$	$(s + t)^2$	$s + l$	$(s \pm l)^2$
221	25	625	26.3	691.69	51.3	2631.69	19.0	361.00	44.0	1936.00	45.3	2052.09
	25	625	26.8	718.24	51.8	2683.24	18.8	353.44	43.8	1918.44	45.6	2079.36
	25	625	26.3	691.69	51.3	2631.69	18.8	353.44	43.8	1918.44	45.1	2034.01
	25	625	26.4	696.96	51.4	2641.96	21.1	445.21	46.1	2125.21	47.5	2256.25
530	23	529	25.4	645.16	48.4	2342.56	20.6	424.36	43.6	1900.96	46.0	2116.00
	23	529	24.0	576.00	47.0	2209.00	18.5	342.25	41.5	1722.25	42.5	1806.25
	23	529	22.4	501.76	45.4	2061.16	18.1	327.61	41.1	1689.21	40.5	1640.25
	23	529	22.9	524.41	45.9	2106.81	17.6	309.76	40.6	1648.36	40.5	1640.25
	23	529	23.6	556.96	46.9	2199.61	17.0	289.00	40.0	1600.00	40.6	1648.36
447	26	676	25.9	670.81	51.9	2693.61	18.3	334.89	44.3	1962.49	44.2	1953.64
	26	676	28.8	829.44	54.8	3003.04	16.8	282.24	42.8	1831.84	45.6	2079.36
	26	676	22.3	497.29	48.3	2332.89	15.7	246.49	41.7	1738.89	38.0	1444.00
	26	676	24.2	585.64	50.2	2520.04	17.3	299.29	43.3	1874.89	41.5	1722.25
	26	676	25.0	625.00	51.0	2601.00	16.3	265.69	42.3	1789.29	41.3	1705.69
675	25	625	26.3	691.69	51.3	2631.69	23.3	542.89	48.3	2332.89	49.6	2460.16
	25	625	29.1	846.81	54.1	2926.81	22.5	506.25	47.5	2256.25	51.6	2662.56
	25	625	27.3	745.29	52.3	2735.29	23.6	556.96	48.6	2361.96	50;9	2590.81

Subject's number	Age (t)	t^2	R.T. to light (l)	l^2	t + l	$(t + l)^2$	R.T. to sound (s)	s^2	s + t	$(s + t)^2$	s + l	$(s + l)^2$
675	25	625	25.2	635.04	50.2	2520.04	19.8	392.04	44.8	2007.04	45.0	2025.00
	25	625	23.4	547.56	48.4	2342.56	19.9	396.01	44.9	2016.01	43.3	1874.89
611	27	729	23.8	566.44	50.8	2580.64	18.9	357.21	45.9	2106.81	42.7	1823.29
	27	729	29.6	876.16	56.6	3203.56	19.1	364.81	46.1	2125.21	48.7	2371.69
	27	729	28.0	784.00	55.0	3025.00	18.7	349.69	45.7	2088.49	46.7	2180.89
	27	729	24.3	590.49	51.3	2631.69	19.0	361.00	46.0	2116.00	43.3	1874.89
	27	729	23.6	556.96	50.6	2560.36	16.3	265.69	43.3	1874.89	39.9	1592.01
520	24	576	31.8	1011.24	55.8	3113.64	22.8	519.84	46.8	2190.24	54.6	2981.16
	24	576	33.0	1089.00	57.0	3249.00	24.5	600.25	48.5	2352.25	57.5	3306.25
	24	576	32.1	1030.41	56.1	3147.21	24.8	615.04	48.8	2381.44	56.9	3237.61
	24	576	30.4	924.16	54.4	2959.36	21.6	466.56	45.6	2079.36	52.0	2704.00
	24	576	31.1	967.21	55.1	3036.01	22.4	501.76	46.4	2152.96	53.5	2862.25
422	27	729	24.0	576.00	51.0	2601.00	15.1	228.01	42.1	1772.41	39.1	1528.81
	27	729	24.7	610.09	51.7	2672.89	18.0	324.00	45.0	2025.00	42.7	1823.29
	27	729	26.8	718.24	53.8	2894.44	19.3	372.49	46.3	2143.69	46.1	2125.21
	27	729	25.2	635.04	52.2	2724.84	19.0	361.00	46.0	2116.00	44.2	1953.64
	27	729	25.5	650.25	52.5	2756.25	18.2	331.24	45.2	2043.04	43.7	1909.69

Subject's number	Age (t)	t^2	R.T. to light (l)	l^2	t + l	$(t + l)^2$	R.T. to sound (s)	s^2	s + t	$(s + t)^2$	s + l	$(s + l)^2$
103	26	676	48.9	2391.21	74.9	5610.01	38.2	1459.24	64.2	4121.64	87.1	7586.41
	26	676	55.5	3080.25	81.5	6642.25	28.0	784.00	54.0	2916.00	83.5	6972.25
	26	676	33.8	1142.44	59.8	3576.04	23.0	529.00	49.0	2401.00	56.8	3226.24
27	26	676	35.4	1253.16	61.4	3769.96	19.1	364.81	45.1	2034.01	54.5	2970.25
	26	676	34.6	1197.16	60.6	3672.36	19.2	368.64	45.2	2043.04	53.8	2894.44
	26	676	36.2	1310.44	62.2	3868.84	19.0	361.00	45.0	2025.00	55.2	3047.04
	26	676	33.3	1108.89	59.3	3516.49	18.8	353.44	44.8	2007.04	52.1	2714.41
	26	676	34.0	1156.00	60.0	3600.00	18.0	324.00	44.0	1936.00	52.0	2704.00
243	27	729	41.4	1713.96	68.4	4678.56	21.2	449.44	48.2	2323.24	62.6	3918.76
	27	729	45.1	2034.01	72.1	5198.41	21.6	466.56	48.6	2361.96	66.7	4448.89
	27	729	43.8	1918.44	70.8	5012.64	22.6	510.76	49.6	2460.16	66.4	4408.96
	27	729	31.6	998.56	58.6	3433.96	17.7	313.29	44.7	1998.09	49.3	2430.49
	27	729	26.6	707.56	53.6	2872.96	16.8	282.24	43.8	1918.44	43.4	1883.56
209	24	576	28.1	789.61	52.1	2714.41	20.4	416.16	44.4	1971.36	48.5	2352.25
	24	576	27.3	745.29	51.3	2631.69	21.8	475.24	45.8	2097.64	49.1	2410.81
	24	576	31.2	973.44	55.2	3047.04	23.7	561.69	47.7	2275.29	54.9	3014.01
	24	576	29.9	894.01	53.9	2905.21	25.0	625.00	49.0	2401.00	54.9	3014.01

Subject's number	Age (t)	t^2	R.T. to light (l)	l^2	t + l	$(t + l)^2$	R.T. to sound (s)	s^2	s + t	$(s + t)^2$	s + l	$(s + l)^2$
209	24	576	29.2	852.64	53.2	2830.24	25.6	655.36	49.6	2460.16	54.8	3003.04
529	25	625	23.8	566.44	48.8	2381.44	17.2	295.84	42.2	1780.84	41.0	1681.00
	25	625	22.7	515.29	47.7	2275.29	19.0	361.00	44.0	1936.00	41.7	1738.89
	25	625	24.9	620.01	49.9	2490.01	19.7	388.09	44.7	1998.09	44.6	1989.16
	25	625	24.0	576.00	49.0	2401.00	15.5	240.25	40.5	1640.25	39.5	1560.25
	25	625	22.0	484.00	47.0	2209.00	20.2	408.04	45.2	2043.04	42.2	1780.84
71	24	576	34.1	1162.81	58.1	3375.61	19.0	361.00	43.0	1849.00	53.1	2819.61
	24	576	34.0	1156.00	58.0	3364.00	21.3	453.69	45.3	2052.09	55.3	3058.09
	24	576	33.1	1095.61	57.1	3260.41	19.5	380.25	43.5	1892.25	52.6	2766.76
	24	576	31.5	992.25	55.5	3080.25	18.7	349.69	42.7	1823.29	50.2	2520.04
	24	576	30.2	912.04	54.2	2937.64	18.6	345.96	42.6	1814.76	48.8	2381.44
524	24	576	38.1	1451.61	62.1	3856.41	20.6	424.36	44.6	1989.16	58.7	3445.69
	24	576	42.0	1764.00	66.0	4356.00	21.0	441.00	45.0	2025.00	63.0	3969.00
	24	576	39.5	1560.25	63.5	4032.25	19.5	380.25	43.5	1892.25	59.0	3481.00
	24	576	39.1	1528.81	63.1	3981.61	17.8	316.84	41.8	1747.24	56.9	3237.61
	24	576	40.5	1640.25	64.5	4160.25	21.3	453.69	45.3	2052.09	61.8	3819.24
8	28	784	44.9	2016.01	72.9	5314.41	32.6	1062.76	60.6	3672.36	77.5	6006.25

Subject's number	Age (t)	t^2	R.T. to light (l)	l^2	t + l	$(t + l)^2$	R.T. to sound (s)	s^2	s + t	$(s + t)^2$	s + l	$(s + l)^2$
8	28	784	43.6	1900.96	71.6	5126.56	25.1	630.01	53.1	2819.61	68.7	4719.69
	28	784	42.7	1823.29	70.7	4998.49	24.5	600.25	52.5	2756.25	67.2	4515.84
678	24	576	57.2	3271.84	81.2	6593.44	30.6	936.36	54.6	2981.16	87.8	7708.84
	24	576	49.5	2450.25	73.5	5402.25	28.2	795.24	52.2	2724.84	77.7	6037.29
	24	576	38.0	1444.00	62.0	3844.00	22.7	515.29	46.7	2180.89	60.7	3684.49
572	26	676	41.2	1697.44	67.2	4515.84	24.3	590.49	50.3	2530.09	65.5	4290.25
	26	676	40.4	1632.16	66.4	4408.96	24.4	595.36	50.4	2540.16	64.8	4199.04
	26	676	40.2	1616.04	66.2	4382.44	21.6	466.56	47.6	2265.76	61.8	3819.24
683	24	576	63.1	3981.61	87.1	7586.41	48.9	2391.21	72.9	5314.41	112.0	12544.00
	24	576	60.2	3624.04	84.2	7089.64	49.0	2401.00	73.0	5329.00	109.2	11924.64
	24	576	40.7	1656.49	64.7	4186.09	21.4	457.96	45.4	2061.16	62.1	3856.41
239	29	841	38.3	1466.89	67.3	4529.29	20.4	416.16	49.4	2440.36	58.7	3445.69
	29	841	37.0	1369.00	66.0	4356.00	21.2	449.44	50.2	2520.04	58.2	3387.24
	29	841	37.8	1428.84	66.8	4462.24	22.6	510.76	51.6	2662.56	60.4	3648.16
250	23	529	45.8	2097.64	68.8	4733.44	35.4	1253.16	58.4	3410.56	81.2	6593.44
	23	529	47.4	2246.76	70.4	4956.16	25.2	635.04	48.2	2323.24	72.6	5270.76
	23	529	38.5	1482.25	61.5	3782.25	20.4	416.16	43.4	1883.56	58.9	3469.21

Subject's number	Age (t)	t^2	R.T. to light (l)	l^2	t + l	$(t + l)^2$	R.T. to sound (s)	s^2	s + t	$(s + t)^2$	s + l	$(s + l)^2$
359	27	729	35.6	1267.36	62.6	3918.76	23.9	571.21	50.9	2590.81	59.5	3540.25
	27	729	33.0	1089.00	60.0	3600.00	18.2	331.24	45.2	2043.04	51.2	2621.44
	27	729	32.8	1075.84	59.8	3576.04	17.8	316.84	44.8	2007.04	50.6	2560.36
526	24	576	38.7	1497.69	62.7	3931.29	23.1	533.61	47.1	2218.41	61.8	3819.24
	24	576	42.4	1797.76	66.4	4408.96	25.3	640.09	49.3	2430.49	67.7	4583.29
	24	576	39.9	1592.01	63.9	4083.21	23.1	533.61	47.1	2218.41	63.0	3969.00
24	23	529	50.0	2500.00	73.0	5329.00	33.6	1128.96	56.6	3203.56	83.6	6988.96
	23	529	49.2	2420.64	72.2	5212.84	30.2	912.04	53.2	2830.24	79.4	6304.36
	23	529	46.8	2190.24	69.8	4872.04	29.2	852.64	52.2	2724.84	76.0	5776.00
342	27	729	36.2	1310.44	63.2	3994.24	20.2	408.04	47.2	2227.84	56.4	3180.96
	27	729	48.9	2391.21	75.9	5760.81	22.0	484.00	49.0	2401.00	70.9	5026.81
	27	729	41.2	1697.44	68.2	4651.24	24.2	585.64	51.2	2621.44	65.4	4277.16
156	23	529	33.2	1102.24	56.2	3158.44	17.0	289.00	40.0	1600.00	50.2	2520.04
	23	529	33.1	1095.61	56.1	3147.21	20.1	404.01	43.1	1857.61	53.2	2830.24
	23	529	34.5	1190.25	57.5	3306.25	18.6	345.96	41.6	1730.56	53.1	2819.61
130	26	676	34.6	1197.16	60.6	3672.36	20.8	432.64	46.8	2190.24	55.4	3069.16
	26	676	32.8	1075.84	58.8	3457.44	19.0	361.00	45.0	2025.00	51.8	2683.24

Subject's number	Age (t)	t^2	R.T. to light (l)	l^2	t + l	$(t + l)^2$	R.T. to sound (s)	s^2	s + t	$(s + t)^2$	s + l	$(s + l)^2$
130	26	676	32.6	1062.76	58.6	3433.96	22.1	488.41	48.1	2313.61	54.7	2992.09
527	25	625	46.9	2199.61	71.9	5169.61	35.8	1281.64	60.8	3694.64	82.7	6839.29
	25	625	46.6	2171.56	71.6	5126.56	30.4	924.16	55.4	3069.16	77.0	5929.00
	25	625	43.1	1857.61	68.1	4637.61	34.6	1197.16	59.6	3552.16	77.7	6037.29
556	25	625	37.4	1398.76	62.4	3893.76	27.0	729.00	52.0	2704.00	64.4	4147.36
	25	625	33.9	1149.21	58.9	3469.21	21.9	479.61	46.9	2199.61	55.8	3113.64
	25	625	34.9	1218.01	59.9	3588.01	26.6	707.56	51.6	2662.56	61.5	3782.25
54	26	676	36.2	1310.44	62.2	3868.84	22.2	492.84	48.2	2323.24	58.4	3410.56
	26	676	36.4	1324.96	62.4	3893.76	27.7	767.29	53.7	2883.69	64.1	4108.81
	26	676	38.2	1459.24	64.2	4121.64	26.1	681.21	52.1	2714.41	64.3	4134.49
310	23	529	38.6	1489.96	61.6	3794.56	22.4	501.76	45.4	2061.16	61.0	3721.00
	23	529	42.8	1831.84	65.8	4329.64	24.5	600.25	47.5	2256.25	67.3	4529.29
	23	529	47.2	2227.84	70.2	4928.04	27.8	772.84	50.8	2580.64	75.0	5625.00
146	22	484	40.7	1656.49	62.7	3931.29	18.6	345.96	40.6	1648.36	59.3	3516.49
	22	484	35.4	1253.16	57.4	3294.76	16.4	268.96	38.4	1474.56	51.8	2683.24
	22	484	35.6	1267.36	57.6	3317.76	17.9	320.41	39.9	1592.01	53.5	2862.25
268	23	529	28.6	817.96	51.6	2662.56	21.6	466.56	44.6	1989.16	50.2	2520.04

Subject's number	Age (t)	t^2	R.T. to light (l)	l^2	t + l	$(t + l)^2$	R.T. to sound (s)	s^2	s + t	$(s + t)^2$	s + l	$(s + l)^2$
268	23	529	27.0	729.00	50.0	2500.00	19.1	364.81	42.1	1772.41	46.1	2125.21
	23	529	26.1	681.21	49.1	2410.81	19.0	361.00	42.0	1764.00	45.1	2034.01
213	29	841	45.8	2097.64	74.8	5595.04	33.3	1108.89	62.3	3881.29	79.1	6256.81
	29	841	38.3	1466.89	67.3	4529.29	28.8	829.44	57.8	3340.84	67.1	4502.41
	29	841	42.2	1780.84	71.2	5069.44	30.8	948.64	59.8	3576.04	73.0	5329.00
483	30	900	41.6	1730.56	71.6	5126.56	25.3	640.09	55.3	3058.09	66.9	4475.61
	30	900	50.4	2540.16	80.4	6464.16	27.6	761.76	57.6	3317.76	78.0	6084.00
	30	900	34.8	1211.04	64.8	4199.04	22.4	501.76	52.4	2745.76	57.2	3271.84
681	25	625	41.0	1681.00	66.0	4356.00	27.5	756.25	52.5	2756.25	68.5	4692.25
	25	625	36.7	1346.89	61.7	3806.89	31.5	992.25	56.5	3192.25	68.2	4651.24
	25	625	36.5	1332.25	61.5	3782.25	31.4	985.96	56.4	3180.96	67.9	4610.41
374	24	576	31.9	1017.61	55.9	3124.81	26.0	676.00	50.0	2500.00	57.9	3352.41
	24	576	38.0	1444.00	62.0	3844.00	26.4	696.96	50.4	2540.16	64.4	4147.36
	24	576	36.0	1296.00	60.0	3600.00	23.9	571.21	47.9	2294.41	59.9	3588.01
557	26	676	35.4	1253.16	61.4	3769.96	22.6	510.76	48.6	2361.96	58.0	3364.00
	26	676	32.6	1062.76	58.6	3433.96	22.7	515.29	48.7	2371.69	55.3	3058.09
	26	676	26.5	702.25	52.5	2756.25	23.3	542.89	49.3	2430.49	49.8	2480.04

Subject's number	Age (t)	t^2	R.T. to light (l)	l^2	t + l	$(t + l)^2$	R.T. to sound (s)	s^2	s + t	$(s + t)^2$	s + l	$(s + l)^2$
543	26	676	70.6	4984.36	96.6	9331.56	47.7	2275.29	73.7	5431.69	118.3	13994.89
	26	676	53.5	2862.25	79.5	6320.25	43.4	1883.56	69.4	4816.36	96.9	9389.61
	26	676	62.9	3956.41	88.9	7903.21	64.8	4199.04	90.8	8244.64	127.7	16307.29
	26	676	44.5	1980.25	70.5	4970.25	30.4	924.16	56.4	3180.96	74.9	5610.01
1003	23	529	43.5	1892.25	66.5	4422.25	25.8	665.64	48.8	2381.44	69.3	4802.49
1004	33	1089	39.7	1576.09	72.7	5285.29	28.1	789.61	61.1	3733.21	67.8	4596.84
1005	35	1225	42.5	1806.25	77.5	6006.25	25.0	625.00	60.0	3600.00	67.5	4556.25
117	24	576	49.5	2450.25	73.5	5402.25	98.0	9604.00	122.0	14884.00	147.5	21756.25
	24	576	45.6	2079.36	69.6	4844.16	26.4	696.96	50.4	2540.16	72.0	5184.00
	24	576	49.5	2450.25	73.5	5402.25	43.6	1900.96	67.6	4569.76	93.1	8667.61
604	24	576	33.4	1115.56	57.4	3294.76	23.2	538.24	47.2	2227.84	56.6	3203.56
	24	576	29.2	852.64	53.2	2830.24	22.1	488.41	46.1	2125.21	51.3	2631.69
	24	576	27.8	772.84	51.8	2683.24	18.2	331.24	42.2	1780.84	46.0	2116.00
418	25	625	38.6	1489.96	63.6	4044.96	17.8	316.84	42.8	1831.84	56.4	3180.96
	25	625	34.4	1183.36	59.4	3528.36	17.0	289.00	42.0	1764.00	51.4	2641.96
	25	625	34.1	1162.81	59.1	3492.81	18.8	353.44	43.8	1918.44	52.9	2798.41
202	26	676	36.6	1339.56	62.6	3918.76	22.0	484.00	48.0	2304.00	58.6	3433.96

Subject's number	Age (t)	t^2	R.T. to light (l)	l^2	t + l	$(t + l)^2$	R.T. to sound (s)	s^2	s + t	$(s + t)^2$	s + l	$(s + l)^2$
202	26	676	33.4	1115.56	59.4	3528.36	19.8	392.04	45.8	2097.64	53.2	2830.24
	26	676	33.6	1128.96	59.6	3552.16	21.2	449.44	47.2	2227.84	54.8	3003.04
262	27	729	35.5	1260.25	62.5	3906.25	20.6	424.36	47.6	2265.76	56.1	3147.21
	27	729	37.8	1428.84	64.8	4199.04	21.5	462.25	48.5	2352.25	59.3	3516.49
	27	729	36.4	1324.96	63.4	4019.56	23.2	538.24	50.2	2520.04	59.6	3552.16
539	25	625	244.8	59927.04	269.8	72792.04	208.4	43430.56	233.4	54475.56	453.2	205390.24
	25	625	216.6	46915.56	241.6	58370.56	184.0	33856.00	209.0	43681.00	400.6	160480.36
	25	625	217.5	47306.25	242.5	58806.25	240.9	58032.81	265.9	70702.81	458.4	210130.56
608	30	900	44.0	1936.00	74.0	5476.00	27.6	761.76	57.6	3317.76	71.6	5126.56
	30	900	38.5	1482.25	68.5	4692.25	23.9	571.21	53.9	2905.21	62.4	3893.76
	30	900	42.6	1814.76	72.6	5270.76	27.4	750.76	57.4	3294.76	70.0	4900.00
528	22	484	39.6	1568.16	61.6	3794.56	22.0	484.00	44.0	1936.00	61.6	3794.56
	22	484	36.4	1324.96	58.4	3410.56	21.7	470.89	43.7	1909.69	58.1	3375.61
	22	484	36.9	1361.61	58.9	3469.21	22.5	506.25	44.5	1980.25	59.4	3528.36
216	26	676	41.0	1681.00	67.0	4489.00	24.5	600.25	50.5	2550.25	65.5	4290.25
	26	676	39.5	1560.25	65.5	4290.25	22.9	524.41	48.9	2391.21	62.4	3893.76
	26	676	37.0	1369.00	63.0	3969.00	20.7	428.49	46.7	2180.89	57.7	3329.29

Subject's number	Age (t)	t^2	R.T. to light (l)	l^2	t + l	$(t + l)^2$	R.T. to sound (s)	s^2	s + t	$(s + t)^2$	s + l	$(s + l)^2$
368	29	841	29.9	894.01	58.9	3469.21	19.4	376.36	48.4	2342.56	49.3	2430.49
	29	841	28.6	817.96	57.6	3317.76	21.0	441.00	50.0	2500.00	49.6	2460.16
	29	841	29.0	841.00	58.0	3364.00	23.2	538.24	52.2	2724.84	52.2	2724.84
107	23	529	47.0	2209.00	70.0	4900.00	35.8	1281.64	58.8	3457.44	82.8	6855.84
	23	529	37.9	1436.41	60.9	3708.81	25.1	630.01	48.1	2313.61	63.0	3969.00
	23	529	36.4	1324.96	59.4	3528.36	22.3	497.29	45.3	2052.09	58.7	3445.69
682	28	784	41.5	1722.25	69.5	4830.25	20.4	416.16	48.4	2342.56	61.9	3831.61
	28	784	34.4	1183.36	62.4	3893.76	21.1	445.21	49.1	2410.81	55.5	3080.25
	28	784	37.5	1406.25	65.5	4290.25	21.8	475.24	49.8	2480.04	59.3	3516.49
162	23	529	31.0	961.00	54.0	2916.00	27.2	739.84	50.2	2520.04	58.2	3387.24
	23	529	30.8	948.64	53.8	2894.44	24.1	580.81	47.1	2218.41	54.9	3014.01
	23	529	30.8	948.64	53.8	2894.44	23.8	566.44	46.8	2190.24	54.6	2981.16
TOTAL 215	5437	138355	8063.1	427822.21	13500.5	974687.91	5647.5	269039.33	11084.5	692948.13	13710.6	1353674.44
MEAN	25.29	643.51	37.5	1989.87	62.8	4533.43	26.3	1251.34	55.56	3223.01	63.8	6296.16

T A B L E xxi.

AVERAGE READINGS OF THOSE CLINICALLY FIT TO DRIVE.

Table xxi Alcohol Readings - Clinically Fit to Drive.

		l	l^2	s	s^2
Totals	167	5369.6	180172.62	3559.1	67362.67
Mean		32.15	1078.87	21.31	403.37

T A B L E xxii.

READINGS FROM THOSE CLINICALLY UNFIT TO DRIVE.

Table xxii **Unfit to Drive Clinically.**

Subject's number	Age (t)	t^2	R.T. to light (l)	l^2	t + l	$(t + l)^2$	R.T. to sound (s)	s^2	s + t	$(s + t)^2$	s + l	$(s + l)^2$
378	26	676	35.4	1253.16	61.4	3769.96	28.7	823.69	54.7	2992.09	64.1	4108.81
	26	676	34.0	1156.00	60.0	3600.00	37.4	1398.76	63.4	4019.56	71.4	5097.96
	26	676	35.4	1253.16	61.4	3769.96	33.8	1142.44	59.8	3576.04	69.2	4788.64
	26	676	35.3	1246.09	61.3	3757.69	36.9	1361.61	62.9	3956.41	72.2	5212.84
	26	676	36.2	1310.44	62.3	3881.29	31.4	985.96	57.4	3294.76	67.6	4569.76
103	26	676	39.3	1544.49	65.3	4264.09	25.0	625.00	51.0	2601.00	64.3	4134.49
	26	676	48.3	2332.89	74.3	5520.49	43.9	1927.21	69.9	4886.01	92.2	8500.84
	26	676	48.9	2391.21	74.9	5610.01	38.2	1459.24	64.2	4121.64	87.1	7586.41
	26	676	55.5	3080.25	81.5	6642.25	28.0	784.00	54.0	2916.00	83.5	6972.25
243	27	729	45.1	2034.01	72.1	5198.41	21.6	466.56	48.6	2361.96	66.7	4448.89
	27	729	43.8	1918.44	70.8	5012.64	22.6	510.76	49.6	2460.16	66.4	4408.96
	27	729	31.6	998.56	58.6	3433.96	17.7	313.29	44.7	1998.09	49.3	2430.49
8	28	784	44.9	2016.01	72.9	5314.41	32.6	1062.76	60.6	3672.36	77.5	6006.25
	28	784	43.6	1900.96	71.6	5126.56	25.1	630.01	53.1	2819.61	68.7	4719.69
	28	784	42.7	1823.29	70.7	4998.49	24.5	600.25	52.5	2756.25	67.2	4515.84
678	24	576	57.2	3271.84	81.2	6593.44	30.6	936.36	54.6	2981.16	87.8	7708.84
	24	576	49.5	2450.25	73.5	5402.25	28.2	795.24	52.2	2724.84	77.7	6037.29

Subject's number	Age (t)	t^2	R.T. to light (l)	l^2	t + l	$(t + l)^2$	R.T. to sound (s)	s^2	s + t	$(s + t)^2$	s + l	$(s + l)^2$
683	24	576	63.1	3981.61	87.1	7586.41	48.9	2391.21	72.9	5314.41	112.0	12544.00
	24	576	60.2	3624.04	84.2	7089.64	49.0	2401.00	73.0	5329.00	109.2	11924.64
250	23	529	45.8	2097.64	68.8	4733.44	35.4	1253.16	58.4	3410.56	81.2	6593.44
	23	529	47.4	2246.76	70.4	4956.16	25.2	635.04	48.2	2323.24	72.6	5270.76
342	27	729	48.9	2391.21	75.9	5760.81	22.0	484.00	49.0	2401.00	70.9	5026.81
	27	729	41.2	1697.44	68.2	4651.24	24.2	585.64	51.2	2621.44	65.4	4277.16
556	25	625	37.4	1398.76	62.4	3893.76	27.0	729.00	52.0	2704.00	64.4	4147.36
	25	625	33.9	1149.21	58.9	3469.21	21.9	479.61	46.9	2199.61	55.8	3113.64
	25	625	34.9	1218.01	59.9	3588.01	26.6	707.56	51.6	2662.56	61.5	3782.25
213	29	841	45.8	2097.64	74.8	5595.04	33.3	1108.89	62.3	3881.29	79.1	6256.81
	29	841	42.2	1780.84	71.2	5069.44	30.8	948.64	59.8	3576.04	73.0	5329.00
483	30	900	50.4	2540.16	80.4	6464.16	27.6	761.76	57.6	3317.76	78.0	6084.00
557	26	676	35.4	1253.16	61.4	3769.96	22.6	510.76	48.6	2361.96	58.0	3364.00
543	26	676	70.6	4984.36	96.6	9331.56	47.7	2275.29	73.7	5431.69	118.3	13994.89
	26	676	53.5	2862.25	79.5	6320.25	43.4	1883.56	69.4	4816.36	96.9	9389.61
	26	676	62.9	3956.41	88.9	7903.21	64.8	4199.04	90.8	8244.64	127.7	16307.29
	26	676	44.5	1980.25	70.5	4970.25	30.4	924.16	56.4	3180.96	74.9	5610.01

Subject's number	Age (t)	t^2	R.T. to light (l)	l^2	t + l	$(t + l)^2$	R.T. to sound (s)	s^2	s + t	$(s + t)^2$	s + l	$(s + l)^2$
1003	23	529	43.5	1892.25	66.5	4422.25	25.8	665.64	48.8	2381.44	69.3	4802.49
1004	33	1089	39.7	1576.09	72.7	5285.29	28.1	789.61	61.1	3733.21	67.8	4596.84
1005	35	1225	42.5	1806.25	77.5	6006.25	25.0	625.00	60.0	3600.00	67.5	4556.25
117	24	576	49.5	2450.25	73.5	5402.25	98.0	9604.00	122.0	14884.00	147.5	21756.25
	24	576	45.6	2079.36	69.6	4844.16	26.4	696.96	50.4	2540.16	72.0	5184.00
	24	576	49.5	2450.25	73.5	5402.25	43.6	1900.96	67.6	4569.76	93.1	8667.61
539	25	625	244.8	59927.04	269.8	72792.04	208.4	43430.56	233.4	54475.56	453.2	205390.24
	25	625	216.6	46915.56	241.6	58370.56	184.0	33856.00	209.0	43681.00	400.6	160480.36
	25	625	217.5	47306.25	242.5	58806.25	240.9	58032.81	265.9	70702.81	458.4	210130.56
608	30	900	44.0	1936.00	74.0	5476.00	27.6	761.76	57.6	3317.76	71.6	5126.56
528	22	484	39.6	1568.16	61.6	3794.56	22.0	484.00	44.0	1936.00	61.6	3794.56
	22	484	36.4	1324.96	58.4	3410.56	21.7	470.89	43.7	1909.69	58.1	3375.61
	22	484	36.9	1361.61	58.9	3469.21	22.5	506.25	44.5	1980.25	59.4	3528.36
608	30	900	42.6	1814.76	72.6	5270.76	27.4	750.76	57.4	3294.76	70.0	4900.00
TOTAL 48	1252	32978	2693.5	247649.59	3945.6	419800.84	2088.4	201676.66	3340.4	330920.86	4781.9	860553.61
MEAN	26.1	687.0	56.1	5159.36	82.2	8745.85	43.5	4201.59	69.6	6894.18	99.6	17928.2

	Age (t)	t^2	R.T. to light (l)	l^2	t + l	$(t + l)^2$	R.T. to sound (s)	s^2	s + t	$(s + t)^2$	s + l	$(s + l)^2$
TOTALS OMITTING SUBJECT 539 (45)	1177	31103	2014.6	93500.74	3191.7	229831.99	1455.1	66357.29	2632.1	162061.49	3469.7	284552.45
MEAN	26.2	691.18	44.77	2077.79	70.93	5107.38	32.34	1474.60	58.49	3601.37	77.10	6323.39

T A B L E xxiii.

RELATIVE INCREASE DUE TO ALCOHOL IN THOSE SUBJECTS CLINICALLY FIT TO DRIVE.

Table xxiii Relative Increase Due to Alcohol - Clinically Fit to Drive.

1 = Reaction time to light.
s = Reaction time to sound.
E = Normal reading (average of total readings).
D = Alcohol reading (-do-).

Subject's number	E_1	D_1	$D_1 - E_1$	E_s	D_s	$D_s - E_s$
20	28.66	27.10	-1.56	21.18	20.76	-0.42
531	30.13	30.90	+0.77	19.93	20.54	+0.61
280	25.97	26.18	+0.21	17.71	20.50	+2.79
221	29.39	26.54	-2.85	20.57	19.62	-0.95
530	25.35	23.66	-1.69	18.38	18.36	-0.02
447	28.74	25.24	-3.50	18.42	16.88	-1.54
675	25.75	26.26	+0.51	19.61	21.82	+2.21
611	27.10	25.86	-1.24	18.14	18.40	+0.26
520	28.58	31.68	+3.10	19.98	23.22	+3.24
422	26.16	25.22	-0.94	17.74	17.92	+0.18
191	22.78	20.52	-2.26	17.40	16.74	-0.66
355	24.25	24.16	-0.09	17.44	17.54	+0.10
103	26.18	33.8	+7.62	18.15	23.0	+4.85

Subject's number	E_1	D_1	$D_1 - E_1$	E_s	D_s	$D_s - E_s$
27	30.5	34.7	+4.2	18.8	18.8	0
243	26.2	34.0	+7.8	14.3	19.0	+4.7
209	28.3	29.14	+0.84	19.2	23.3	+4.1
529	21.7	23.5	+1.8	14.8	18.3	+3.5
71	27.2	32.6	+5.4	17.8	19.4	+1.6
524	33.7	39.8	+6.1	15.4	20.0	+4.6
678	32.2	38.0	+5.8	18.0	22.7	+4.7
572	35.3	40.6	+5.3	17.4	23.4	+6.0
683	31.4	40.7	+9.3	22.6	21.4	-1.2
239	33.2	37.7	+4.5	24.9	21.4	-3.5
250	33.1	38.5	+5.4	14.8	20.4	+5.6
359	29.7	33.8	+4.1	16.3	19.9	+3.6
526	32.5	40.3	+7.8	20.4	23.8	+3.4
24	37.4	48.6	+11.2	18.8	31.0	+12.2
342	34.7	36.2	+1.5	19.4	20.2	+0.8
156	28.2	33.6	+5.4	17.6	18.6	+1.0
130	29.5	33.3	+3.8	14.8	20.6	+5.8

Subject's number	E_1	D_1	$D_1 - E_1$	E_s	D_s	$D_s - E_s$
527	33.3	45.5	+12.2	20.5	33.6	+13.1
54	29.7	36.9	+7.2	21.0	25.3	+4.3
310	32.2	42.8	+10.6	18.1	24.9	+6.8
146	33.0	37.2	+4.2	18.4	17.6	-0.8
268	25.8	27.2	+1.4	19.8	19.9	+0.1
213	33.6	38.3	+4.7	28.3	28.8	+0.5
483	28.2	38.2	+10.0	18.0	23.8	+5.8
681	32.8	38.1	+5.3	20.7	30.1	+9.4
374	27.4	35.3	+7.9	17.6	25.4	+7.8
682	24.7	37.8	+13.1	17.4	21.1	+3.7
557	23.2	29.5	+6.3	17.0	23.0	+6.0
604	26.5	30.1	+3.6	19.2	21.2	+2.0
418	32.2	35.7	+3.5	18.2	17.9	-0.3
202	33.0	34.5	+1.5	18.2	21.0	+2.8
262	32.9	36.6	+3.7	20.0	21.8	+1.8
608	28.0	38.5	+10.5	15.0	23.9	+8.9
162	25.1	30.9	+5.8	18.0	25.0	+7.0

Subject's number	E_1	D_1	$D_1 - E_1$	E_s	D_s	$D_s - E_s$
216	30.4	39.2	+8.8	18.2	22.7	+4.5
107	30.8	40.4	+9.6	23.2	27.7	+4.5
534	23.0	29.3	+6.3	18.8	22.4	+3.6
368	22.9	29.2	+6.3	17.0	21.2	+4.2
<u>TOTAL</u> 51			230.82			163.25
<u>MEAN</u>			4.53			3.20

TABLE xxiv.

RELATIVE INCREASE DUE TO ALCOHOL IN THE SUBJECTS CLINICALLY UNFIT TO DRIVE.

Table xxiv Relative Increase Due to Alcohol - Clinically Unfit to Drive.

1 = Reaction time to light.
s = Reaction time to sound.
E = Normal reading (average of total readings).
D = Alcohol reading (-do-).

Subject's number	E_1	D_1	$D_1 - E_1$	E_s	D_s	$D_s - E_s$
378	30.4	35.3	+4.9	23.4	33.6	+10.2
103	26.2	48.0	+21.8	18.2	33.8	+15.6
243	26.2	40.5	+14.3	14.3	20.6	+6.3
8	30.8	43.7	+12.9	13.3	27.4	+14.1
678	32.2	53.3	+21.1	18.0	29.4	+11.4
683	31.4	61.7	+30.3	22.6	49.0	+26.4
250	31.3	46.6	+15.3	14.8	30.3	+15.5
342	34.7	45.1	+10.4	19.4	23.1	+3.7
556	26.1	35.4	+9.3	19.1	25.2	+6.1
213	33.6	44.0	+10.4	28.3	32.1	+3.8
483	28.2	50.4	+22.2	18.0	27.6	+9.6
557	23.2	35.4	+12.2	17.0	22.6	+5.6
543	33.9	57.9	+24.0	23.8	46.6	+22.8

Subject's number	E_1	D_1	$D_1 - E_1$	E_s	D_s	$D_s - E_s$
1003	33.5	43.5	+10.0	17.9	25.8	+7.9
1004	33.9	39.7	+5.8	17.1	28.1	+11.0
1005	31.7	42.5	+10.8	18.1	25.0	+6.9
117	34.0	48.2	+14.2	21.6	56.0	+34.4
539	30.4	226.3	+195.9	19.0	211.1	+192.1
608	28.0	43.3	+15.3	15.0	27.5	+12.5
528	31.4	37.6	+6.2	18.4	22.1	+3.7
<u>TOTAL</u> 20			467.3			419.6
<u>MEAN</u>			23.37			20.98
<u>TOTALS OMITTING SUBJECT 539</u> (19)			271.4			227.5
<u>MEAN</u>			14.28			11.97

TABLE xxv.

TABLES SHOWING THE CALCULATION OF THE STANDARD DEVIATION OF THE REACTION TIMES TO LIGHT AND SOUND. BY GROUPING.

Reaction Time to Light -- Normals -- 407 Readings.

Groups.	f	d	fd	fd^2
19.0 - 20.5	7	-6	-42	252
20.6 - 22.1	17	-5	-85	425
22.2 - 23.7	32	-4	-128	512
23.8 - 25.3	45	-3	-135	405
25.4 - 26.9	45	-2	-90	180
27.0 - 28.5	50	-1	-50	50
28.6 - 30.1	65	0	0	0
30.2 - 31.7	49	+1	+49	49
31.8 - 33.3	41	+2	+82	164
33.4 - 34.9	30	+3	+90	270
35.0 - 36.5	13	+4	+52	208
36.6 - 38.1	6	+5	+30	150
38.2 - 39.7	4	+6	+24	144
39.8 - 41.3	2	+7	+14	98
41.4 - 42.9	1	+8	+8	64
			-181	2971

$$c = \frac{-181}{407} = -0.44 \quad \therefore \quad c^2 = 0.1936$$

$$s^2 = \frac{2971}{406} = 5.23$$

$$\sigma^2 = s^2 - c^2 = 5.23 - 0.1936 = 5.04$$

in terms of class intervals

Class interval = 1.5

$$\therefore \text{ True } \sigma^2 = 5.04 \times (1.5)^2 = 5.04 \times 2.25$$

$$= 11.34$$

$$\therefore \sigma = 3.37$$

Reaction Time to Sound -- Normals -- 407 Readings.

Groups.	f	d	fd	fd^2
12.0 - 13.2	5	-5	-25	125
13.3 - 14.5	12	-4	-48	192
14.6 - 15.8	46	-3	-138	414
15.9 - 17.1	57	-2	-114	228
17.2 - 18.4	73	-1	-73	73
18.5 - 19.7	76	0	0	0
19.8 - 21.0	61	1	61	61
21.1 - 22.3	33	2	66	132
22.4 - 23.6	20	3	60	180
23.7 - 24.9	12	4	48	192
25.0 - 26.2	8	5	40	200
26.3 - 27.5	2	6	12	72
27.6 - 28.8	1	7	7	49
28.9 - 30.1	0	8	0	0
30.2 - 31.4	1	9	9	81
			-95	2049

$c = \frac{-95}{407} = -0.233 \quad \therefore \; c^2 = 0.06$

$s^2 = \frac{2049}{406} = 5.05$

$\sigma^2 = s^2 - c^2 = 5.05 - 0.06 = 4.99$

in terms of class intervals.

$\therefore$ True $\sigma^2 = 4.99 \times (1.2)^2$

$= 4.99 \times 1.44 = 7.09$

$\therefore \; \sigma = 2.66$

Reaction Time to Light -- Alcoholics -- Fit to Drive Clinically -- 167 Readings.

Groups.	f	d	fd	fd^2
19.0 - 21.0	3	-6	-18	108
21.1 - 23.1	8	-5	-40	200
23.2 - 25.2	20	-4	-80	320
25.3 - 27.3	22	-3	-66	198
27.4 - 29.4	13	-2	-26	52
29.5 - 31.5	14	-1	-14	14
31.6 - 33.6	18	0	0	0
33.7 - 35.7	16	+1	+16	16
35.8 - 37.8	15	+2	+30	60
37.9 - 39.9	16	+3	+48	144
40.0 - 42.0	12	+4	+48	192
42.1 - 44.1	3	+5	+15	75
44.2 - 46.2	0	+6	+0	0
46.3 - 48.3	5	+7	+35	245
48.4 - 50.4	2	+8	16	128
			-36	1752

$$c = \frac{-36}{167} = -0.216 \quad \therefore \quad c^2 = 0.0467$$

$$s^2 = \frac{1752}{166} = 10.55$$

$$\sigma^2 = s^2 - c^2 = 10.55 - 0.0467 = 10.5$$

in terms of class intervals

$$\therefore \text{ True } \sigma^2 = 10.5 \times (2)^2 = 10.454 \times 4 = 42.0$$

$$\therefore \sigma = 6.48$$

Reaction Time to Sound -- Alcohol Readings -- Fit to Drive Clinically -- 167 Readings.

Groups.	f	d	fd	fd^2
15.0 - 16.3	8	-4	-32	128
16.4 - 17.7	13	-3	-39	117
17.8 - 19.1	36	-2	-72	144
19.2 - 20.5	24	-1	-24	24
20.6 - 21.9	27	0	0	0
22.0 - 23.3	24	+1	+24	24
23.4 - 24.7	12	+2	+24	48
24.8 - 26.1	8	+3	+24	72
26.2 - 27.5	3	+4	+12	48
27.6 - 28.9	3	+5	+15	75
29.0 - 30.3	2	+6	+12	72
30.4 - 31.7	3	+7	+21	147
31.8 - 33.1	0	+8	0	0
33.2 - 34.5	1	+9	+9	81
34.6 - 35.9	3	+10	+30	300
			+4	1280

$$c = \frac{+4}{167} = +0.024 \quad \therefore \quad c^2 = 0.000576$$

$$s^2 = \frac{1280}{166} = 7.71$$

$$\sigma^2 = s^2 - c^2 = 7.71 - 0.000576 = 7.71 \text{ approx.}$$

in terms of class intervals

Class interval = 1.3

$$\therefore \text{ True } \sigma^2 = 7.71 \times (1.3)^2$$

$$= 7.71 \times 1.69 = 13.03$$

$$\therefore \sigma = 3.61$$

Reaction Time to Light -- Alcoholics - Unfit to Drive --

48 Readings.

Groups.	f	d	fd	fd^2
31.0 - 46.0	29	-6	-174	1044
46.1 - 61.1	13	-5	-65	325
61.2 - 76.2	3	-4	-12	48
76.3 - 91.3	0	-3	0	0
91.4 - 106.4	0	-2	0	0
106.5 - 121.5	0	-1	0	0
121.6 - 136.6	0	0	0	0
136.7 - 151.7	0	+1	0	0
151.8 - 166.8	0	+2	0	0
166.9 - 181.9	0	+3	0	0
190.0 - 205.0	0	+4	0	0
205.1 - 220.1	2	+5	+10	50
220.2 - 235.2	0	+6	0	0
235.3 - 250.3	1	+7	+7	49
			-234	1516

$$c = \frac{-234}{48} = -4.88 \therefore c^2 = 23.8144$$

$$s^2 = \frac{1516}{47} = 32.26$$

$$\sigma^2 = s^2 - c^2 = 32.26 - 23.81 = 8.45$$

in terms of class intervals

$$\therefore \text{True } \sigma^2 = 8.45 \times (\text{class interval})^2$$

$$= 8.45 \times (15)^2 = 8.45 \times 225$$

$$= 1911.25$$

$$\therefore \sigma = 43.71$$

Reaction Time to Sound -- Alcoholics Unfit to Drive

Clinically -- All Readings Included 48.

Groups.	f	d	fd	fd^2
17.0 - 32.9	31	-6	-186	+1116
33.0 - 48.9	11	-5	-55	275
49.0 - 64.9	2	-4	-8	32
65.0 - 80.9	0	-3	-0	0
81.0 - 96.9	0	-2	-0	0
97.0 - 112.9	1	-1	-1	1
113.0 - 128.9	0	0	0	0
129.0 - 144.9	0	+1	0	0
145.0 - 160.9	0	+2	0	0
161.0 - 176.9	0	+3	0	0
177.0 - 192.9	1	+4	+4	16
193.0 - 208.9	1	+5	+5	25
209.0 - 224.9	0	+6	0	0
225.0 - 240.9	1	+7	+7	49
			-234	1514

$c = \frac{-234}{48} = -4.88 \therefore c^2 = 23.8144$

$s^2 = \frac{1514}{47} = 32.21$

$\sigma^2 = s^2 - c^2 = 32.21 - 23.81 = 8.4$

in terms of class intervals.

Class interval = 15.9

$\therefore$ True $\sigma^2 = 8.4 \times (15.9)^2$

$= 8.4 \times 252.81 = 2123.6$

$\therefore \sigma = 45.09$

Reaction Time to Light -- Alcohol Readings -- Unfit to Drive

Clinically -- Omitting Subject 539 -- 45 Readings.

Class Interval 2.6

Groups.	f	d	fd	fd^2
31.6 - 34.2	3	-4	-12	48
34.3 - 36.9	8	-3	-24	72
37.0 - 39.6	3	-2	-6	12
39.7 - 42.3	3	-1	-3	3
42.4 - 45.0	9	0	0	0
45.1 - 47.7	5	1	5	5
47.8 - 50.4	7	2	14	28
50.5 - 53.1	0	3	0	0
53.2 - 55.8	2	4	8	32
55.9 - 58.5	1	5	5	25
58.6 - 61.2	1	6	6	36
61.3 - 63.9	2	7	14	98
64.0 - 66.6	0	8	0	0
66.7 - 69.3	0	9	0	0
69.4 - 72.0	1	10	10	100
			+17	459

$$c = \frac{+17}{45} = +0.378 \therefore c^2 = 0.1429$$

$$s^2 = \frac{459}{44} = 10.43$$

$$\sigma^2 = s^2 - c^2 = 10.43 - 0.1429 = 10.29$$

in terms of class intervals.

Class interval = 2.6

$$\therefore \text{True } \sigma^2 = 10.29 \times (2.6)^2$$

$$= 10.29 \times 6.76 = 69.56$$

$$\therefore \sigma = 8.34$$

Mean = 44.68

__Reaction Time to Sound -- Alcohol Readings -- Unfit to Drive__

__Clinically -- Omitting Subject 539 -- 45 Readings.__

__Class Interval 5.5__

Groups.	f	d	fd	fd^2
17.5 - 23.0	9	-2	-18	+36
23.1 - 28.6	16	-1	-16	16
28.7 - 34.2	8	0	0	0
34.3 - 39.8	4	1	4	4
39.9 - 45.4	3	2	6	12
45.5 - 51.0	3	3	9	27
51.1 - 56.6	0	4	0	0
56.7 - 62.2	0	5	0	0
62.3 - 67.8	1	6	6	36
67.9 - 73.4	0	7	0	0
73.5 - 79.0	0	8	0	0
79.1 - 84.6	0	9	0	0
84.7 - 90.2	0	10	0	0
90.3 - 95.8	0	11	0	0
95.9 -101.4	1	12	12	144
			+3	275

$c = \frac{+3}{45} = 0.067 \quad \therefore \; c^2 = 0.0045$

$s^2 = \frac{275}{44} = 6.25$

$\sigma^2 = s^2 - c^2 = 6.25 - 0.067 = 6.183$

in terms of class intervals.

Class interval = 5.5

$\therefore$ True $\sigma^2 = 6.183 \times (5.5)^2$

$= 6.183 \times 30.25 = 187.04$

$\therefore \; \sigma = 13.74$

__Mean__ = __31.87__

Relative Increase in Reaction Time to Light due to Alcohol

($D_1 - E_1$) -- Clinically Fit to Drive -- 51 Readings.

Class Interval 1.1

Groups.	f	d	fd	fd^2
-3.5 - -2.4	2	-6	-12	72
-2.3 - -1.2	4	-5	-20	100
-1.1 - 0	2	-4	-8	32
+0.1 - +1.2	4	-3	-12	36
+1.3 - +2.4	4	-2	-8	16
2.5 - 3.6	3	-1	-3	3
3.7 - 4.8	7	0	0	0
4.9 - 6.0	7	1	7	7
6.1 - 7.2	5	2	10	20
7.3 - 8.4	4	3	12	36
8.5 - 9.6	3	4	12	48
9.7 - 10.8	3	5	15	75
10.9 - 12.0	1	6	6	36
12.1 - 13.2	2	7	14	98
			+13	579

$$c = \frac{+13}{51} = +0.255 \quad \therefore \; c^2 = 0.065$$

$$s^2 = \frac{579}{50} = 11.58$$

$$\sigma^2 = s^2 - c^2 = 11.58 - 0.065 = 11.52$$

in terms of class intervals.

Class interval = 1.1

$$\therefore \text{True } \sigma^2 = 11.52 \times (1.1)^2$$

$$= 11.52 \times 1.21 = 13.94$$

$$\therefore \sigma = 3.63$$

Relative Increase in Reaction Time to Sound Due to Alcohol

(D_s - E_s) -- Clinically Fit to Drive -- 51 Readings.

Class Interval 1.1

Groups.	f	d	fd	fd^2
-3.5 - -2.4	1	-5	-5	25
-2.3 - -1.2	2	-4	-8	32
-1.1 - 0	7	-3	-21	63
+0.1 - +1.2	8	-2	-16	32
1.3 - 2.4	4	-1	-4	4
2.5 - 3.6	7	0	0	0
3.7 - 4.8	10	1	10	10
4.9 - 6.0	5	2	10	20
6.1 - 7.2	2	3	6	18
7.3 - 8.4	1	4	4	16
8.5 - 9.6	2	5	10	50
9.7 - 10.8	0	6	0	0
10.9 - 12.0	0	7	0	0
12.1 - 13.2	2	8	16	128
			+2	398

$$c = \frac{+2}{51} = 0.04 \quad \therefore \quad c^2 = 0.0016$$

$$s^2 = \frac{398}{50} = 7.96$$

$$\sigma^2 = s^2 - c^2 = 7.96 - 0.0016 = 7.958$$

in terms of class intervals.

Class interval = 1.1

$$\therefore \text{True } \sigma^2 = 7.958 \times (1.1)^2$$

$$= 7.958 \times 1.21 = 9.63$$

$$\therefore \sigma = 3.103$$

Relative Increase in Reaction Time to Light due to Alcohol

($D_1 - E_1$) -- Clinically Unfit to Drive -- 20 Readings.

Class Interval 14

Groups.	f	d	fd	fd^2
4.0 - 18.0	14	-1	-14	14
18.1 - 32.1	5	0	0	-
32.2 - 46.2	-	+1	0	-
46.3 - 60.3	-	2	0	-
60.4 - 74.4	-	3	0	-
74.5 - 88.5	-	4	0	-
88.6 - 102.6	-	5	0	-
102.7 - 116.7	-	6	0	-
116.8 - 130.8	-	7	0	-
130.9 - 144.9	-	8	0	-
145.0 - 159.0	-	9	0	-
159.1 - 173.1	-	10	0	-
173.2 - 187.2	-	11	0	-
187.3 - 201.3	1	12	12	144
			-2	158

$$c = \frac{-2}{20} = -0.1 \quad \therefore \quad c^2 = 0.01$$

$$s^2 = \frac{158}{19} = 8.3$$

$$\sigma^2 = s^2 - c^2 = 8.3 - 0.01 = 8.29$$

in terms of class intervals.

Class interval = 14

$$\therefore \text{True } \sigma^2 = 8.29 \times (14)^2$$

$$= 8.29 \times 196 = 1624.8$$

$$\therefore \sigma = 40.31$$

Relative Increase in Reaction Time to Sound due to Alcohol

$(D_s - E_s)$ -- Clinically Unfit to Drive -- 20 Readings.

Class Interval 13

Groups.	f	d	fd	fd^2
3.7 - 16.7	16	-1	-16	16
16.8 - 29.8	2	0	0	0
29.9 - 42.9	1	+1	+ 1	1
43.0 - 56.0	-	2	-	-
56.1 - 69.1	-	3	-	-
69.2 - 82.2	-	4	-	-
82.3 - 95.3	-	5	-	-
95.4 -108.4	-	6	-	-
108.5 -112.5	-	7	-	-
121.6 -134.6	-	8	-	-
134.7 -147.7	-	9	-	-
147.8 -160.8	-	10	-	-
160.9 -173.9	-	11	-	-
174.0 -187.0	-	12	-	-
187.1 -200.1	1	13	13	169
			-2	186

$$c = \frac{-2}{20} = -0.1 \quad \therefore \quad c^2 = 0.01$$

$$s^2 = \frac{186}{19} = 9.8$$

$$\sigma^2 = s^2 - c^2 = 9.8 - 0.01 = 9.79$$

in terms of class intervals.

Class interval 13

$$\text{True } \sigma^2 = 9.79 \times (13)^2 = 9.79 \times 169$$

$$= 1654.5$$

$$\therefore \sigma = 40.67$$

Relative Increase in Reaction Time to Light due to Alcohol

D_1 - E_1 -- Clinically Unfit to Drive -- Omitting Extreme Reading -- 19 Readings.

Class Interval 1.7

Groups.	f	d	fd	fd^2
4.9 - 6.6	3	-5	-15	75
6.7 - 8.4	0	-4	0	0
8.5 -10.2	2	-3	- 6	18
10.3 -12.0	3	-2	- 6	12
12.1 -13.8	2	-1	- 2	2
13.9 -15.6	4	0	0	0
15.7 -17.4	0	+1	0	0
17.5 -19.2	0	2	0	0
19.3 -21.0	0	3	0	0
21.1 -22.8	3	4	12	48
22.9 -24.6	1	5	5	25
24.7 -26.4	0	6	0	0
26.5 -28.2	0	7	0	0
28.3 -30.0	0	8	0	0
30.1 -31.8	1	9	9	81
			-3	261

$c = \frac{-3}{19} = -0.158$

$\therefore c^2 = 0.025$

$\sigma^2 = s^2 - c^2 \qquad s^2 = \frac{261}{18} = 14.5$

$= 14.5 - 0.025 = 14.475$ in terms of class intervals.

$\therefore$ true $\sigma^2 = 14.475 \times (1.7)^2$

$= 2.89 \times 14.475$

$= 41.83$

$\therefore \sigma \qquad = 6.47$

Relative Increase in Reaction Time to Sound due to Alcohol

$D_s - E_s$ -- Clinically Unfit to Drive -- Omitting Extreme Readings -- 19 Readings.

Class Interval 2.1

Groups.	f	d	fd	fd^2
3.7 - 5.8	4	-3	-12	36
5.9 - 8.0	4	-2	-8	16
8.1 - 10.2	2	-1	-2	2
10.3 - 12.4	2	0	0	0
12.5 - 14.6	2	1	+2	2
14.7 - 16.8	2	2	4	8
16.9 - 19.0	0	3	0	0
19.1 - 21.2	0	4	0	0
21.3 - 23.4	1	5	5	25
23.5 - 25.6	0	6	0	0
25.7 - 27.8	1	7	7	49
27.9 - 30.0	0	8	0	0
30.1 - 32.2	0	9	0	0
32.3 - 34.4	1	10	10	100
			+6	238

$$c = \frac{+6}{19} = +0.316 \quad \therefore \; c^2 = 0.0999 = 0.1$$

$$s^2 = \frac{238}{18} = 13.2$$

$$\sigma^2 = s^2 - c^2 = 13.2 - 0.1 = 13.1$$

in terms of class intervals.

$$\therefore \text{ True } \sigma^2 = 13.1 \times (2.1)^2$$

$$= 13.1 \times 4.41 = 57.77$$

$$\therefore \; \sigma = 7.6$$